1954 Russian Model Engine Book

What follows is an edited computer-generated English translation of a 100 page book published in 1954 by DOSAAF, a para-military State-run organization responsible among other things for encouraging Russian youth to gain technical skills and aeronautical insights through participation in aeromodelling. The idea was that such experience might constitute an appropriate preparation for later service to the State as pilots, aircraft designers, aircraft technicians and the like. Alternatively, the participants might develop into successful Soviet representatives at International model aircraft competitions, thereby enhancing Soviet prestige.

The author of the book was A. V. Filipichev, one of the most prominent Russian model engine designers of the early post-WW2 period. He worked at the Central Aircraft Modelling Laboratory (CAML) in Moscow, where many of the pioneering Russian designs were developed. A significant number of the engines featured in this book were designed by Filipichev himself.

The text presented here is taken from the 1954 second edition of a book by the same author which first appeared in 1951. It is unique in that it provides the most complete available documentation of the state of Russian model engine design thinking and manufacturing as of the 1940's and early 1950's. It is particularly valuable as a historical reference for the light that it throws upon Russian model engines from the early post-WW2 era. Many of the designs covered are described and illustrated in no other reference of which I am aware and hence would be completely lost today if it were not for this book.

*The rather poor quality of many of the engine images which appear here is explained by the fact that they were based upon scans taken by a Russian source from the book itself. They are included regardless because in many cases they are the **sole** surviving images of the engines concerned, at least as far as I have been able to determine. Surely **any** image is far better than none?!?*

Detailed instructions and plans were provided for building the 1.8 cc CAML-50 diesel and the 10 cc F-4 "Bumlebee" spark ignition model, along with details of a number of other then-current or then-recent Russian designs. Perhaps reflecting the limited availability of such accessories in the USSR during the Iron Curtain era, the book also provides detailed instructions on how to make one's own spark ignition coils, spark plugs, glow plugs and other engine-related accessories. Those sections have been omitted from this translation since they are of little historical or technical significance today. In addition, most of the numerical formulae, tables and charts as well as some of the images confused the OCR (optical character reader), hence not scanning clearly and having to be omitted.

Regardless, I hope that you find something of interest in these pages. Apart from a few comments and images inserted for clarity and some editorial re-phrasing into colloquial English, the test is exactly as written by Filipichev himself. That said, any errors in

translation and interpretation are solely my responsibility as Editor of this English translation.

A. V. Filipichev

MINIATURE PISTON ENGINES FOR FLYING MODELS

Second Edition, Revised

DOSAAF, Moscow 1954

This book is recommended for model enthusiasts involved in the design and construction of flying model aircraft and the miniature engines used to power them. It summarizes the many years of experience in the design, construction and operation of model aero engines at the Central Aircraft Model Laboratory (CAML) in Moscow. The book also introduces readers to existing Soviet engines for flying models.

The book includes working drawings of two model aero engines with descriptions, based upon which you can build these engines yourself. The miniature engines described in the book can also be installed on working models of boats, cars, sleds, etc.

The book is the revised second edition of the book by A. V. Filipichev entitled "*Piston Engines for Flying Models*", published by DOSAAF in 1951.

Author's note

Aeromodelling is an exciting sport. At model aircraft competitions held annually in the Soviet Union, models with various power sources participate. The most interesting are those with mechanical engines. All models, and many of the engines participating in competitions, are built by modellers on their own.

By the 1954 date of this second edition's publication, the record performances of free flight and radio controlled models were as follows:

Duration - 6 hr 1 min

Speed - 129 km/hr

Distance - 378.756 km

Altitude - 4150 m

The rapid increases in record performances have been made possible solely thanks to the ongoing work of aeromodellers to improve the performance of their models. The motor is the heart of the aircraft, therefore having to meet high standards. In models flying over long distances, the motor must be able to operate continuously for many hours. In speed models, the motor must develop very high power for short periods. Some model aero engines running on special fuel mixtures can develop outputs of up to 1.5 BHP. Such a motor may weigh only about 350 gm.

Model aero engines have displacements ranging from 0.3 cc to 10 cc. According to the sporting rules of the International Aviation Federation (FAI), the displacements of engines for flying models should not exceed 10 cc. Depending on their displacements, the engines are divided into three classes: Class I - with a displacement of up to 2.5 cc; Class II - with a displacement of up to 5 cc; and Class III - with a displacement of up to 10 cc.

For those who wish to design and construct their own motors, this book includes the working drawings and full design details of the CAML-50 and "Bumblebee" model aero engines, along with brief descriptions of their construction. When following these drawings, it is possible to make changes in the design of the motors to solve construction problems and to respond to different requirements such as limitations in available equipment.

For example, if casting the crankcase is difficult or impossible, then an equivalent can be made from a solid piece of metal, perhaps slightly changing the contours and mounting arrangements. If it is not possible to braze the bypass channel, it is necessary to change the design so that the bypass can be incorporated without brazing. Instead of a cylinder liner and a separate duralumin head, an all-steel cylinder can be made, etc. Such construction challenges provide an opportunity to develop what amounts to a new motor design in relation to the technical capabilities of the designer/constructor and will develop the skills required for independent creativity and design.

The book outlines methods for manufacturing motor parts in workshops staffed by trainee technicians, school students and participants in collectives. Most of the materials necessary for the manufacture of motors will usually be available in the same workshops in the form of waste materials and old worn machine parts.

If, after reading this book, aeromodellers and young technicians are inspired to become involved in the design and construction of model engines and to work to improve the performances of our homeland representatives at competitions, the author will consider that his efforts were not in vain.

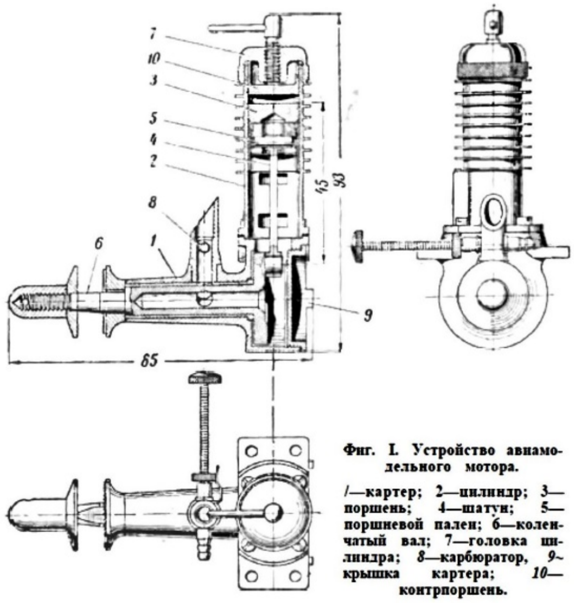
All advancements in the manufacture and development of new designs of model aero engines, as well as comments on this book, are requested to be reported to the address:

Oborongiz
51, Moscow
Petrovka 24

<u>Chapter 1 - Purpose of Engine Components and Working Principles</u>

General Information

Model aero engines operate on a reciprocating cycle. The use of a two-stroke cycle in such a motor significantly reduces the cost of the unit, simplifies its construction and reduces weight due to the absence of valves and their control mechanism. Two times more power strokes than a four-cycle motor make the motor run more smoothly and allows the use of a flywheel of smaller size (and consequently, a smaller weight).



Фиг. I. Устройство авиамодельного мотора.

1—картер; 2—цилиндр; 3—поршень; 4—шатун; 5—поршневой пален; 6—коленчатый вал; 7—головка цилиндра; 8—карбюратор, 9—крышка картера; 10—контрпоршень.

In a two-stroke engine, the fuel mixture is sucked into the crankcase and then transferred to the cylinder through a bypass. Thus, the fuel mixture comes into contact with all the friction-generating surfaces of the motor. This permits the significant simplification of the lubrication of parts by adding oil directly to the fuel.

In view of the above advantages, two-stroke engines have become the most widely used types in aeromodelling. Despite their small size, light weight and extremely simple operating principles, model aero motors essentially consist of the same main components as full-sized units. For reference during what follows, a section of a typical model aero engine is shown at the left.

Crankcase and crankshaft assembly

The crankcase connects the engine parts to each other. The cylinder is attached to it, and there is a main bearing in the front housing (sometimes integral with the crankcase and sometimes detachable) in which the crankshaft rotates. If the engine is a spark ignition type, a contact breaker is mounted on the front of the main bearing. To install the motor in the model or on the test stand, the crankcase usually has special mounting lugs.

The crankcase cavity in which the crankweb rotates and the connecting rod operates is hermetically sealed. In the crankcase cavity, the piston alternately creates a vacuum, then a compression. Thus, in conjunction with the piston, the crankcase acts as a transfer gas pump.

On the crankweb there is a crankpin connected to the piston by a connecting rod and gudgeon pin. This whole system of articulated moving parts is called the piston/connecting rod assembly or reciprocating assembly.

Cylinder and piston

At the appropriate moment, a mixture of fuel and air is burned in the engine cylinder, resulting in a sharp increase in pressure above the piston. Under the influence of this pressure, the piston moves downward, doing useful work. The inner surface of the cylinder along which the piston moves directs the movement of the piston and is called the wall of the cylinder. The very small gap between the piston and cylinder walls in the presence of lubrication makes it possible to compress the gases in the cylinder head very strongly when the piston moves up.

The volume enclosed between the crown of the piston at top dead center (TDC) and the inner surface of the cylinder head is called the combustion chamber. This is where the burning of the fuel mixture takes place.

The volume enclosed between the crown of the piston at bottom dead center (BDC) and the inner surface of the cylinder head is called the total volume of the cylinder. The ratio of the total volume of the cylinder to the volume of the combustion chamber is called the geometric compression ratio.

Internal combustion engines are classified by displacement. The displacement is the cylinder volume displaced (or “swept”) by the piston when it moves from BDC to TDC

Flywheel

The crankshaft rotates unevenly when the engine is running. During the power stroke, when the combustion gas pressure acts upon the piston, the shaft rotation speed increases. When the piston goes up and compresses the working mixture, the rotation speed decreases. These oscillations of the shaft rotation speed during one revolution are significantly smoothed by the inertial forces of the rotating flywheel.

During operation of the engine, the flywheel accumulates energy during the power stroke and then uses the accumulated energy to drive the connecting rod-piston mechanism past the dead spots and through the compression stage, also rotating the crankshaft of the motor to suck the fuel mixture into the crankcase, to transfer it to the cylinder and then to compress it.

The function of the flywheel in model aero engines is performed by the airscrew and the rotating counterweighted crankweb.

Chapter 2 - Principles of Engine Operation

Induction and carburetion

The model aero engine has a tube for the intake of air. The intake tube is traversed by a far thinner tube with a small hole (the jet), which supplies liquid fuel mixture. This small tube is called a spraybar. For most motors, the cross section of the bore which supplies

fuel to the jet is regulated by a tapered needle, which is necessary to adjust the exact amount of fuel entering the motor.

The system consisting of the intake tube, the spraybar and the adjusting needle is a simple carburetor that serves to prepare the working mixture for use in the engine.

Suction in two-stroke engines results from the vacuum created in the cavity of the crankcase when the piston moves up. If the engine is a piston-port (sideport) design, then as soon as the piston opens the induction port of the inlet tube, air rushes at high speed into the low-pressure interior of the crankcase. Passing through the suction pipe at high speed, it lowers the pressure in it, making it less than atmospheric. Due to this decrease in pressure in the intake tube, the fuel supplied through the fuel line from the tank starts to flow out of the jet. The escaping fuel is atomized by the passing air, evaporating and forming a working mixture of vaporized fuel and air. This process is illustrated below at the right.

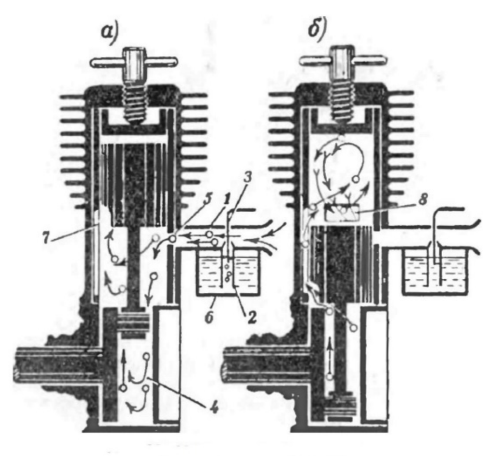
Having reached TDC, the piston begins to move down and closes the induction port from the intake tube. This completes the preparation and induction of the working fuel mixture.

A working mixture is a mixture of fuel vapors (the smallest possible droplets of fuel) with air in the ratio required for complete combustion of the fuel. For example, the combustion of 1 gm of gasoline requires about 15 gm of air. Different flammable liquids require different amounts of air (or rather, oxygen contained in the air) for their complete combustion.

An ideal working mixture which allows the complete utilization of all fuel and free oxygen in combustion is called the normal working mixture. A working mixture in which the amount of air is less than theoretically necessary is called a rich mixture. A working mixture in which the amount of air is more than theoretically necessary is called a lean mixture. Rich and lean mixtures are less inflammable and burn slower than a normal working mixture. Excessively enriched or lean mixtures lose their ability to ignite and are unsuitable for the effective operation of the motor.

Compression in the crankcase and combustion chamber

As it moves down during the power stroke, the piston compresses the working mixture in the crankcase. Some way short of BDC, the piston first opens the cylinder's exhaust port and then its transfer port (see the figure at the right). The latter port is connected to the crankcase by the bypass passage. The compressed working mixture in the crankcase rushes through the transfer port into the cylinder.



The transfer of working mixture into the cylinder continues for some time around BDC and

during the initial upward movement of the piston, potentially until the transfer port closes. Then the piston closes the exhaust port also and begins to compress the working mixture in the combustion chamber. This upward movement is called the compression stroke.

Power stroke and exhaust

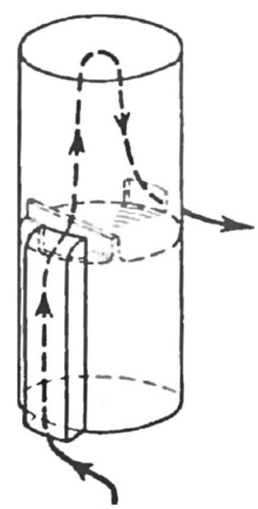
Just before the piston reaches TDC, the working mixture ignites from a spark plug, from a glow-plug or from an increase in temperature as a result of compression of the working mixture - for more details of the ignition process, see Chapter 5. Extremely rapid combustion of the working mixture takes place, with the release of a large amount of heat. The hot gases formed as a result of the combustion of the working mixture expand, and the piston moves downward under the action of the gas pressure force, making a power stroke.

The speed of movement of the piston together with that of the connecting rod and crankshaft system increases rapidly during the power stroke. Consequently, the flywheel (or airscrew) mounted on the opposite end of the crankshaft acquires a certain amount of additional energy, part of which is expended on keeping the system moving after the power stroke ends.

Discharge of exhaust gas (exhaust) occurs near the end of the stroke when the piston opens the exhaust port(s) . Pressurized exhaust gases are released into the atmosphere. After release, the pressure in the cylinder drops rapidly, soon approaching atmospheric.

Scavenging

A little later than the exhaust ports, the transfer port opens and a fresh charge of working mixture enters the cylinder from the crankcase, displacing the remaining exhaust gases from it. This process is called scavenging.



The efficiency of the motor, its power, the stability of its operation and its starting qualities depend to a large extent on the efficiency of the scavenging process. The transfer and exhaust ports and the bypass channels and exhaust stacks must be positioned so as to provide the best possible scavenging, i.e., to clear the cylinder of burnt gases as much as possible while minimizing the premature loss of fresh incoming working mixture.

The piston crown often has a baffle (deflector) that deflects the fresh working mixture upward so that it does not go straight out through the exhaust port located opposite without being burned, as shown in the attached figure at the left. Such a system of scavenging is called cross-flow or transverse loop scavenging.

In a cross-flow loop scavenging system, the mixture is guided by the walls of the bypass channel, the transfer port and the piston baffle (if fitted) to move upwards along the opposite wall of the cylinder, making a path in the cylinder in the form of a loop which goes up into the combustion chamber and then down on the opposite side to the exhaust port(s), pushing out the remaining exhaust gases. Ideally, by the time the fresh working mixture approaches the exhaust port(s), the latter are closed by the piston crown, ending the scavenging process with the fresh mixture still trapped inside.

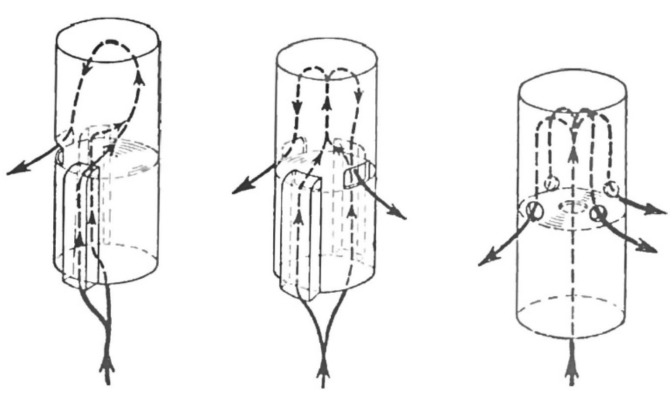
Model aero engines use various other loop scavenging options in addition to cross or transverse flow. The following loop scavenging systems are most commonly used:

1. One transfer port and two exhaust ports. The incoming working mixture is directed across the piston crown to the opposite wall between the exhaust ports and rises up that wall to form a loop. The stream returning downwards is divided into two and heads to the exhaust ports.

2. Two transfer ports with one exhaust port. Two streams of working mixture meet at the wall opposite the exhaust port and, supported by one another, form a common flow loop which is directed to the exhaust port.

3. Cross-flow scavenging with two transfer ports and two exhaust ports located between them. Two streams of working mixture are directed towards each other and slightly upward, meet in the middle and force each other to rise upward, after which they divide into two streams once more and head to the exhaust ports.

4. Radial multiple loop scavenging with multiple transfer ports arranged between multiple exhaust ports. Multiple streams of working mixture form a central fountain which rises in the centre of the cylinder and then descends along the cylinder walls, driving out the exhaust gases.

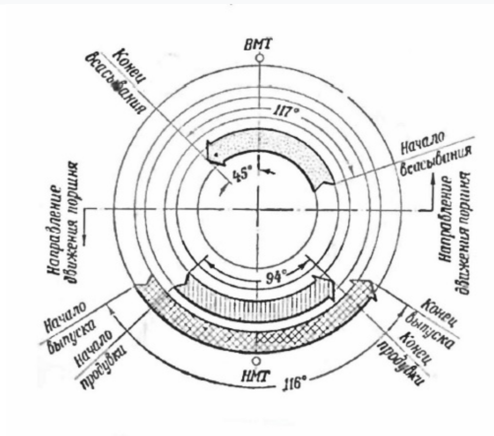


Several of these systems are illustrated in the figure at the left.

In model aero engines, multi-channel transfer systems are also used, having up to 12 transfer ports and 12 exhaust openings. Non-channel systems are also employed, in which transfer takes place through the piston crown (see illustration at the left) The valve in the piston crown in some motors is forced to open mechanically, with assistance from the pressure difference in the cylinder and the crankcase of the motor. The transfer flow of mixture from the center of the piston rises, reverses direction and splits into several streams (according to the number of exhaust ports).

Gas distribution

Gas distribution includes the beginning and end of the inlet of the working mixture (induction) and the beginning and end of the transfer and exhaust periods. These figures significantly affect the power of the engine, the number of revolutions per minute, the fuel consumption and the starting qualities of the motor. The durations of the induction, exhaust and transfer phases are measured in degrees of crankshaft rotation. Exhaust and transfer durations depend on the location of the upper edges of the exhaust and transfer ports above the piston crown at BDC.



A typical timing diagram for a model aero engine (the KMK-1) is shown at the right. The induction of the mixture for this motor occurs through the crankshaft. For example, the diagram tells us that the induction process continues for the time necessary to rotate the shaft by 117 degrees.

Power output

A motor’s power output depends on the displacement of the cylinder, the average effective gas pressure (Brake Mean Effective Pressure) in the cylinder and the number of revolutions or, more precisely, the number of working strokes per unit of time. The term power means the amount of useful work done per unit of time. Model aero engine power is usually expressed in Brake Horse Power (BHP).

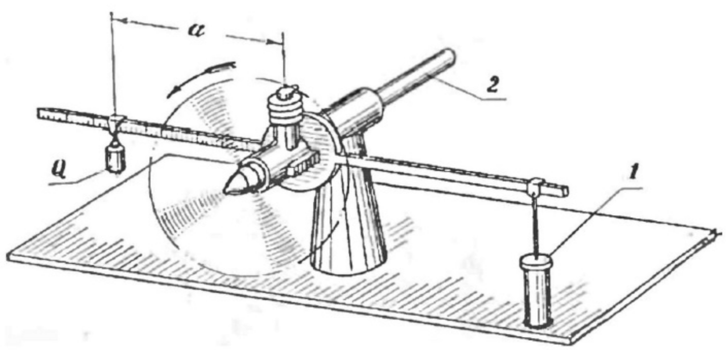
To determine a motor’s power output, it is necessary to know the average effective pressure on the piston crown. This value is a variable even for a given engine and depends on the operating speed, the quality of the fuel, the compression ratio, cooling conditions and the efficiency of the scavenging process. The latter variable in turn depends on the gas distribution diagram, on the area and arrangement of the induction, transfer and exhaust ports, etc.

The effective pressure also depends on engine speed. An increase in the number of revolutions reduces the time for induction and transfer of the working mixture and for scavenging. As a result, the amount of working mixture reaching the combustion chamber is reduced. Different motors develop different effective pressure values, typically lying in the range 2-5 kg/cm^2.

The average effective pressure can be derived by knowing the effective power output. The number of revolutions per minute is measured during the operation of the motor using a rev counter (tachometer). One also needs to know the torque being generated by the motor.

Torque

When the motor is running with an airscrew fitted, then the motor itself, and with it the whole installation, tends to turn in the opposite direction. This is called a reactive moment. Reactive moment arises as a result of the torque being developed by the motor and transmitted to the airscrew. Both torque and reactive moment are numerically equal to each other, but oriented in opposite directions. Hence by measuring the reactive moment, we can determine the magnitude of the torque being applied to the airscrew.



The torque of a model engine is measured on a special balance bar machine, shown in the above figure. The motor mounting is free to rotate on axis 2 in two ball bearings. A oil-filled damper 1 is used to smooth out the “shaking” of the motor. When the motor is running, the horizontal scale with divisions will deviate in the opposite direction to the rotation of the propeller. Then the weight is shifted along the scale to return it to a horizontal position.

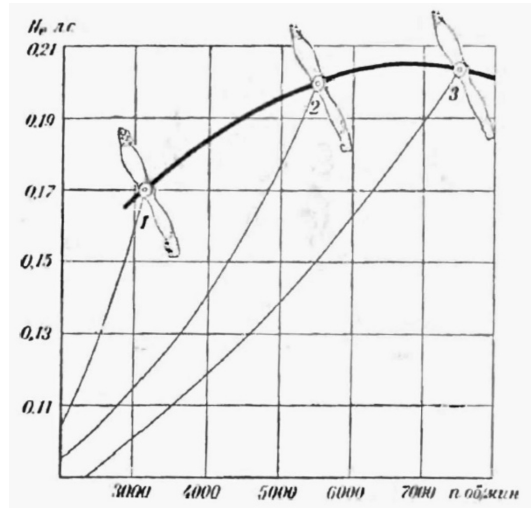
Knowing the mass of the weight and its distance to the axis of rotation of the motor mount,
one can easily determine the torque of the motor. Knowing the torque and speed of the motor, one can now calculate the rate of work being done, which is the effective power of the motor at that speed.

Motor power characteristics

By measuring the torque and speed with a fully open intake, we can determine the maximum effective motor power with this airscrew. The applicable formula shows that the power for a given torque depends on the number of revolutions per minute. To plot this dependence, it is necessary to measure the torque and the number of rotations 3 or 4 times at different positions of the throttle to yield different speeds with the same airscrew. Then, by calculating the power for each number of revolutions, it is possible to plot a graph of the effective power versus the number of revolutions per minute ***for that airscrew***.

This curve is called the throttle response curve. Using this airscrew and the characteristics obtained from it, you can now determine the power of another engine using the same airscrew without measuring the torque. To do this, you need to measure the number of revolutions with the second engine and find the power developed by the originally-tested motor according to its throttle response curve.

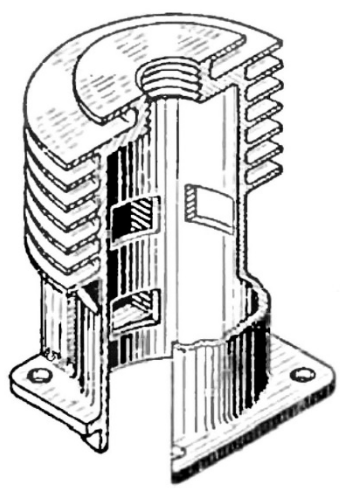
By installing an air-brake on the motor (i.e., an airscrew with removable transverse brake blades) or a series of airscrews having different pitches or diameters whose throttle response curves are known, i.e. changing the load on the engine, we find that the ***maximum*** speed developed by the motor will change with load. By connecting a smooth curve, the maximum full-throttle revolutions for each airscrew or each position of the airbrake blades, we can plot the so-called external motor characteristic (power curve). Using this curve, we can determine the maximum motor power for a given number of revolutions and a fully open throttle.



A typical power curve established in this way using different airscrews with known throttle response curves is shown above at the right.

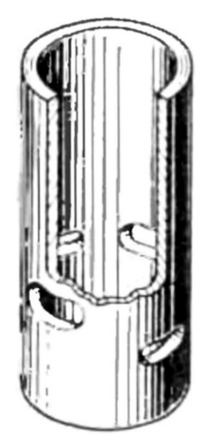
Chapter 3 - Design of the Components

Cylinder



The inner surface of the cylinder must be carefully machined and finished so that the piston can easily slide in it. The combustion of the working mixture occurs in the upper part of the cylinder. Therefore, to remove heat from the cylinder, fins are included that increase the contact surface of the cylinder with the surrounding air. For gas distribution, there are slots (ports) in the walls of the cylinder through which the transfer of the working mixture, the release of burnt gases and scavenging can take place.

It has been established that the best choice for the motor operation is a cylinder machined from solid steel, complete with fins, a head and a mounting flange (as seen at the left). The steel bypass channel can be silver-soldered or brazed in place, which ensures complete gas-tightness of the channel.



In some cases, it is not a complete cylinder that is manufactured, but the sleeve alone (right). The use of a sleeve

in comparison with a complete cylinder has the following ***advantages***:

1) it can be made from a smaller piece of steel;

2) it takes less time to machine the sleeve;

3) before grinding the inner surface, you can bore the sleeve with a reamer, which will reduce the grinding and lapping time;

4) no milling and drilling of the flange is required:

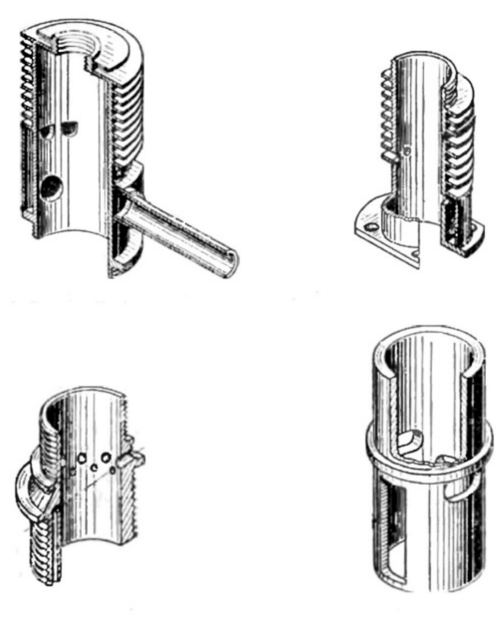
5) there is no soldered bypass channel; the channel is formed externally in the wall of the surrounding crankcase.

The ***disadvantages*** of the sleeve are as follows;

1) an increase in the total weight and bulk of the motor;

2) the need for accurate finishing and fitting of the outer surface of the sleeve to the inner surface of the upper part of the crankcase;

3) the difficulty of ensuring a gas-tight connection between the cylinder head and the top of the sleeve.



The figure at the left shows several cylinder design options. Clockwise from top left - AMM-5, MK-02, F-10 and OK-20. These engines will be discussed in more detail in Chapter 7.

Piston

The piston serves to induce and compress the working mixture, acts as a valve for timing the transfer and exhaust phases and receives the pressure force of the combustion gas during the power stroke. The piston should be lightweight so as not to develop excessive inertial forces during operation. The heavier the piston assembly is, the more energy is required to accelerate it during the power stroke. This energy is not available to drive the airscrew. In addition, the engine will produce more vibration, which also represents wasted potential energy. The lighter the piston/rod assembly is, the more readily the engine is able to make revs, all other things being equal.

The piston must slide easily along the cylinder wall without creating severe scuffing or friction. The piston must maintain a close gap between itself and the cylinder wall but not seize in the cylinder when heated during operation.

The pistons of model aero engines are most often made of steel, cast iron and, more rarely, light alloys, the latter being generally fitted with piston rings. For better compression, the pistons are very carefully machined and fitted to the cylinder. To ensure lubrication and improve compression, shallow circumferential grooves are often machined into the piston wall to collect and retain oil from the cylinder walls. Very high-speed racing engines are frequently made using light alloy pistons with compression rings. This approach significantly reduces both piston weight and friction area, which leads to an increase in motor power.

Gudgeon pin

The piston is flexibly connected to the connecting rod by the gudgeon (wrist) pin. This pin experiences significant loads. Therefore, gudgeon pins are made of high quality heat-treated steel. The surface of the pin must be carefully polished to reduce friction and wear.

To lighten them, gudgeon pins are sometimes centrally drilled along the axis. The diameter of the pin is typically around 25% of the diameter of the cylinder bore.

Connecting rod

As its name suggests, the connecting rod connects the piston with the crankpin of the crankshaft. The rod has upper and lower heads and a column. In model aero engines, heat-treated steel connecting rods made on milling machines or lathes are most often used. Sometimes connecting rods are cast or forged from aluminum alloys. In this case, bronze bushings are generally pressed into the connecting rod bearings. To obtain the lightest-possible connecting rod without reducing its strength, an I-section is often milled into the attached to the connecting rod column. A number of connecting rod designs are shown above at the right.

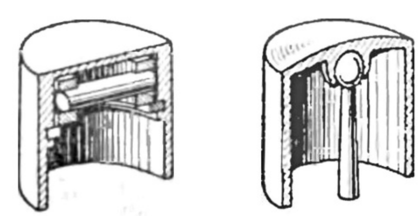
To reduce friction between the lower bearing of the connecting rod and the crankpin, thin rollers are sometimes included, axially retained by special washers. To ensure the free passage of lubricant into the connecting rod bearings, holes and sawn grooves are often provided on the rubbing surfaces of the bearings. The lubricant which enters the bearings through these openings is deposited by the fuel mixture during engine operation.

Piston connections

For low-speed motors, the piston walls can be made relatively thick. In this case, the gudgeon pin is located directly in the walls of the piston since they have a sufficient support area. The pin should fit snugly in the holes. So that the pin does not scratch the cylinder wall, it must be secured against lateral displacement, or special soft metal end-pads should be installed at its ends.

When installing a gudgeon pin in the walls of the piston, the installation can be significantly improved and piston weight reduced by cutting circumferential recesses at the top and bottom of the piston interior and drilling holes for the pin in the resulting internal band. The band can be further lightened by drilling or milling so that only two bosses remain inside the piston, and the walls are lightened. However, this method of lightening the piston is rather complicated.

Another method for connecting the piston to the connecting rod is to cut a thread on the inner surface of the piston. A specially-made duralumin carrier is secured to the connecting rod with a gudgeon pin. The carrier is then screwed into the piston interior. This method is technically simple, and the surface of the piston is not broken by the holes for the pin. The approaches just described are shown on the attached drawing above at the left.

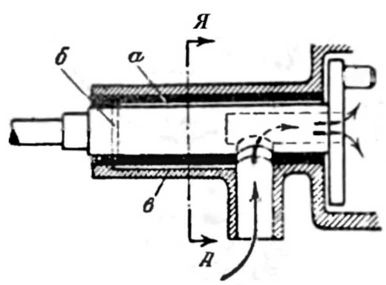


Increasingly frequently lately, pistons have been constructed that do not have skirt ports through their side walls for bypassing the mixture, nor do they have piston baffles or deflectors. This has made it possible not to use a gudgeon pin at all, thereby significantly lightening the piston. In the figure at the right, it can be seen that the upper head of the connecting rod has a spherical shape and is snugly fitted into a special socket below the piston crown. The disadvantage of this ball-and-socket connection is the inability to disassemble the piston and connecting rod.

Another piston connection is shown in the same figure. A thin-walled or lightweight steel sleeve connected to the rod by means of a pin is installed in a thin-walled piston. The sleeve is prevented from popping out of the piston by means of a steel circlip installed in a specially cut groove up to 0.2 mm deep. This ring does not carry any load during engine operation and, when carefully executed, the design works flawlessly. With this design, removal of the rod is quite straightforward by simply removing the circlip.

Crankshaft

The main function of the crankshaft is to convert the reciprocating motion of the piston into rotational motion of the airscrew by way of the connecting rod. In model aero engines, the crankshaft is usually of the cantilever type, i.e., the crankweb is located at the end of the shaft without a second fulcrum. An airscrew is attached to the free end of the shaft protruding from the front of the crankcase. The crankshaft consists of a finely-finished journal, a threaded prop retaining extension, a crankweb (often with a counterweight) and a polished crankpin.



In some motors, the shaft is also used as a rotary valve for the induction of air and fuel into the crankcase. A diagram showing the passage of air into the crankcase through the crankshaft is shown in the attached figure at the left.

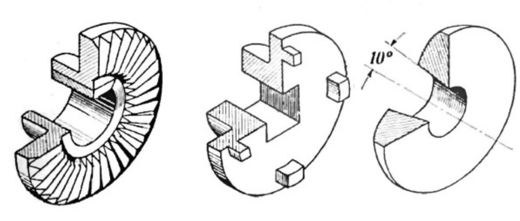
On the web of the crankshaft diametrically opposite to the crankpin is a counterweight, which serves to balance the operation of the motor. Sometimes the shaft with the counterweight is machined from one piece, while in other cases the counterweight is riveted as an additional plate to the main web of the shaft. A hole is often drilled in the crank pin, into which a thread is cut and a screw is screwed that prevents the lower end of the connecting rod from sliding off the crankpin. At other times such a retainer is not included, in which case the connecting rod is prevented from shifting along the axis by the crankcase cover.

In most cases, crankshafts are made from a single billet of steel. Prefabricated crankshafts are also used. The construction of the crankshaft from individual parts is rational for mass production, as this results in a great deal of metal saving and lower cost. Heat treated and polished shaft journals and crankpins are tightly pressed into the holes of the crankweb using special equipment. Some engines use a screw-in crankpin, which must have a left-hand thread to prevent unscrewing during operation in the normal direction.

During the operation of the motor, the shaft experiences high stresses and variable torsional loads. Therefore it must be made very strong. Shafts are usually quench-hardened or case-hardened.

Prop drivers

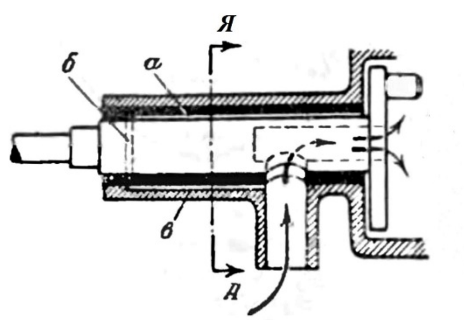
The prop driver is typically mounted on a flat or square section of the forward part of the crankshaft. However, the best mounting system is to fit the prop driver on a cone of 20 °. In this case, the driver always sits correctly, its hole is not subject to wear and the flat on the shaft does not wear out or enlarge the matching socket in the prop driver.



The surface of the prop driver facing the airscrew hub has knurling, notching or special protrusions formed on or in it to prevent the airscrew from slipping. With a large bearing surface on the driver face, making a notch or knurling is not required - with sufficient tightening using the prop-nut, the airscrew is held quite securely.

Main bearings

The main bearings of model aero motors are in most cases a long sleeve made of bronze or cast iron (sometimes hardened steel), pressed into the crankcase front end extension. A lubricating groove is often formed in the upper part of the sleeve on its inner surface, through which oil enters the bearing under pressure from the crankcase when the motor is running.



A more sophisticated lubrication groove pattern that works well when meticulously carried out is shown in the attached figure at the left. When compressed in the crankcase, lubricant in the form of oil mist passes through the crankshaft induction port into the straight groove (a) on the inner wall of the main bearing and moves along the shaft body to the annular groove (b). At the bottom, the annular groove is connected by a hole to the groove (c) cut in the crankcase to the inlet pipe. Thus, this groove promotes oil advancement in the system by suction at the time during which the mixture is being inducted into the crankcase.

To reduce friction, sometimes two short bushings are inserted, one from each end, instead of a long single bushing. However, this system results in more rapid wear.

In engines designed for speed models, the shaft very often rotates on ball bearings. The use of ball bearings makes the motor heavier and also necessitates a seal to eliminate leakage of the working mixture through the bearings. As sealants, rubber or leather rings are used. As a rule, motors with ball bearings can operate at higher speeds than motors with sliding bearings.

Crankcase

The crankcase is the heart of the motor, connecting all the other parts. The motor is usually attached to the frame of the model using bolts passing through mounting lugs which form part of the crankcase.

The crankcase experiences tensile and torsional loads while the motor is running, so it must be rigid. Typically, crankcases are cast from aluminum alloys using metal or sand molds. In the manufacture of experimental engines or small series of motors, crankcases are often machined from a single piece of metal.

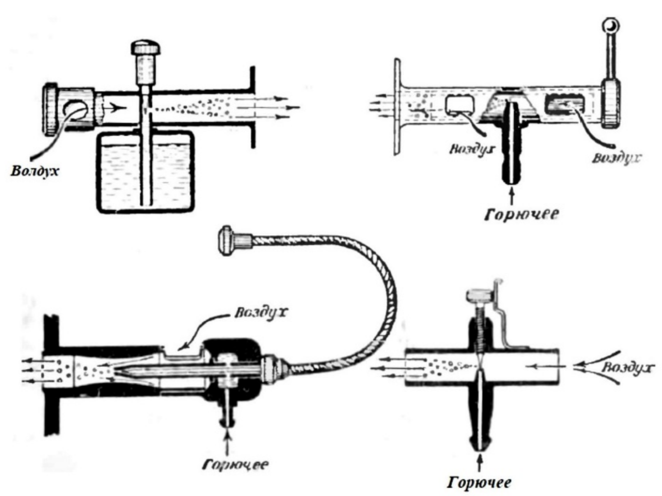
Sometimes the crankcase of a model aero motor is a complex component that combines the crankcase itself, a fuel tank, a carburetor, a bypass channel and exhaust stacks. At the top of such a crankcase is a cylinder liner. Alternatively, the crankcase may be a very simple component which connects the cylinder with the crankshaft and facilitates mounting but does not perform other functions.

Some crankcases have a thread cut into the back wall, into which a backplate is screwed, making the crankcase airtight. In other cases, the rear cover is bolted to the crankcase and may even serve itself to mount the entire motor. In still other cases, the backplate is cast integrally as part of the crankcase. There are complex crankcases consisting of two or three parts which are held together by screws. The variety of forms of crankcases is most often determined by the technology available to its manufacturer and the desire to ensure its strength.

Carburetor

In present-day model aero engines, the simplest carburetors are used, which are easy to manufacture, simple to operate and trouble-free. The most common carburetor designs with various fuel metering devices are shown in the attached figure below at the right.

The main part of the carburetor is a steel or duralumin tube. This tube is called the carburetor intake tube. A second tube passes transversely across it, supplying a combustible liquid through a jet. A hole is drilled on the side surface of the transverse tube or spraybar for the flow of fuel into the intake tube. The flow of fuel is regulated by the tapered end of the screwed-in needle.



At the outer end of the mixing tube, side holes are sometimes drilled, overlapping with similar holes in a cap fitted over the end of the tube to serve as a throttle. By turning the throttle, the amount of incoming air is regulated, and thereby the number of revolutions of the motor. There are many variations of the described arrangement, but in principle they are all basically similar.

A carburetor with air quality control of the mixture is interesting. This arrangement is shown in the above figure at top right. The jet hole in this carburetor is slightly larger than usual and is of fixed size, with no needle. The intake tube is provided with two ports, one on each side of the jet. The openings are controlled by a concentric tube which can be rotated by a lever at the rear.

With the extra window of the inlet tube (at the left in the image) fully closed, the mixture enters the motor enriched due to the oversized jet. This is the starting setting of the system. As soon as the engine starts, rotating the concentric tube using the control lever leans out the mixture by slightly opening the left window. This reduces the amount of air passing through the main right window in front of the jet, and thereby reduces the amount of fuel entering the motor to the correct amount for best performance.

Using this system, the openings in the throttle are made in such a way that when it is turned in the intake tube, the rear (right) aperture gradually opens to its full cross section, then the left aperture also begins to open to the full cross section. In this position, both apertures are fully open. With further rotation of the throttle, the right aperture begins to gradually close until it is completely closed; at this time, the left aperture is fully open. With the help of such a carburetor, having only one governing body, it is possible to achieve a good quality mixture at any speed (within the limits of the capabilities of the particular motor).

Fuel tank

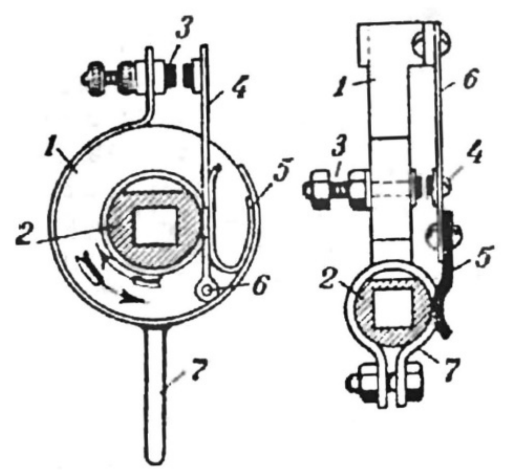
The fuel is brought to the carburetor's jet tube either from a tank mounted on the model and connected to the jet tube using a vinyl, rubber or metal pipe, or directly from a tank attached to the motor. Fuel tanks are made of metal, celluloid or plexiglass. The tank's fuel filling hole should have a plug with a small vent hole for communication with the atmosphere.

Contact breaker

Contact breakers are required only on motors with spark ignition (see Chapter 5) and serve to interrupt the electrical current in the primary winding of the coil. At the moment of opening of the breaker contacts, a spark is generated between the electrodes of the spark plug which ignites the working mixture in the cylinder.

Having tensioned the breaker against unwanted rotation due to the torque exerted by the operating cam on the motor shaft, it is possible to advance the ignition timing of the working mixture by rotating the contact breaker in the opposite direction to the motor's running direction. Ignition timing is affected by the fact that complete combustion of the working mixture from a spark does not occur instantaneously, but only after a certain period of time.

By advancing the point of ignition of the working mixture, we can increase the running speed of the engine and improve the fuel combustion conditions, since by the time the piston arrives at TDC, the entire volume of the working mixture is already in a state of combustion and burns under the most favorable conditions, i.e., at the smallest volume and highest temperature. The greater the engine's operating speed, the more (in degrees) the breaker is moved to advance the spark. In modern high-speed model aero engines, the ignition timing often reaches 40-50 degrees advance ahead of TDC.



Typically, the contact breaker is mounted at the front of the main bearing and is operated by a cam made in one piece with the propeller driver. Several typical breaker devices are shown in the attached figure at the left. Closing and opening of the contacts occurs due to a cut along the chord of the cylindrical part of the cam. The greater the number of revolutions of the motor, the larger the cut-off of the cam should be, otherwise the contact closure time (dwell period) becomes so short that the coil cannot become fully saturated and the motor cannot increase its revolutions. However, for low-speed motors (not more than 4000-5000 rpm), a large cut-out (long dwell period) causes excessive consumption of battery power, since the contact closure time is longer than necessary.

Most contact breakers have a housing with an insulated contact, a moving bar with a contact connected to the engine body, a spring and a cam. The contacts are usually tungsten, sometimes from technical silver. The gap between the contacts is adjustable from 0.2 to 0.4 mm. A suitably-formed handle is attached to the contact breaker body to rotate it as necessary.

<u>Chapter 4 - Fuels and Lubricants</u>

Fuel mixes for gasoline motors

For model aero engines operating using a spark plug with an electrically-induced spark, any aviation or automobile gasoline that does not form soot on the walls of the combustion chamber and on the electrode electrodes can be used.

For lubrication of moving parts during operation of the motor, oil is added to the fuel. The oil is mixed with fuel in proportions from 1 : 10 to I : 5, that is, one part of oil for 5-10 parts of gasoline (the worse the compression seal, the more oil is added to the fuel). Oil should be only fresh unused MK grade, used for lubricating full-sized aero engines. In no case should you use liquid mineral oils or vegetable drying oils. The former will lead to rapid wear of the motor, and the latter will make it impossible to operate the motor after the first start, since all parts become covered with a thin drying film.

Fuel mixes for diesels

For compression ignition (diesel) motors, various combustible liquids or mixtures thereof are used as fuel. The following fuels are used for diesel motors:

1) ethyl ether;

2) petroleum and ether;

3) aviation gasoline;

4) road gasoline;

5) naphtha;

6) kerosene;

7) lamp oil;

8) ethyl alcohol.

Any of these liquids when mixed with oil can serve as a base fuel for the motor. The best results are obtained by mixing a heavy base fuel (kerosene, lamp oil) with lighter fuels (ethyl ether, petroleum and light gasoline). In this case, the motor starts quickly and runs steadily.

Only top-quality MK aviation oil, castor oil and various high-quality automobile oils should be used as lubricants. In model engines, oil is not only included for lubrication. By filling the gaps between the walls of the piston and the cylinder, the oil helps to seal the working clearance, thus improving the compression of gas in the combustion chamber.

Good compression improves starting and increases the life of a diesel. In a diesel, a decrease in compression leads to a drop in the temperature of the compressible mixture and, if that decrease in temperature falls below the working self-ignition limits for a given mixture, then ignition of the fuel will not occur. Therefore, with poor compression, additional oil must be added to the mixture. A large amount of oil passing through the engine will not create any obstacles to its operation and at the same time will significantly improving the cooling of all parts of the motor, especially the piston, with reduced engine wear.

It has been found that a mixture consisting of equal parts of base fuel and oil or even of one part of fuel and one and a half parts of oil is quite suitable for a compression ignition motor. The disadvantage of mixtures with a high oil content is that the oil flows abundantly from the exhaust ports and is sprayed about by the slipstream from the airscrew, coating the model.

The most common mixtures with ether for compression ignition engines are as follows (in percent by volume):

1. *Ethyl ether 33%, kerosene 33%, MK oil 34%*

2. *Ethyl ether.25%, kerosene 25%, Oil 50%*
3. *Ethyl ether 20%, kerosene 55%, mineral oil 25%*
4. *Ethyl ether 36%, kerosene 50%, castor oil 14%*
5. *Ethyl ether 40%, mineral oil 60%*

To obtain maximum power from diesel motors, use the following mixture (in percent by volume):

Ethyl ether 33%, kerosene or lamp oil 33%, castor oil 32%, amyl nitrite 2%

The addition of amyl nitrite to the fuel mixture increases the engine's engine power by up to 25%.This is because it reduces ignition lag time, thereby accelerating the combustion process. It also allows the use of a lower operating compression ratio.

When preparing and storing the mixture, remember that ether is very volatile; if you leave a container holding ether open, then after a few minutes it will evaporate. Therefore, the ether and mixture must be carefully sealed and stored in a cool place. A well-stored mixture can last a very long time.

Ether is included in the mixture to facilitate starting and to some extent reduce the compression ratio required to ignite the mixture. These effects of ether are explained by its very low self-ignition temperature in comparison with other combustibles. In particular, motors with poor compression cannot compress the working mixture sufficiently in the cylinder unless ether is present. The heat generated by compression is not able to ignite the mixture, and the motor cannot be started.

Motors with ***very*** good compression can manage to start and run without the admixture of ether. When the working mixture is compressed, sufficient heat can be developed to ignite fuel with a higher self-ignition point than ether.

The following are a few tested ether-free mixtures (percent by volume):

1. *Aviation gasoline 60%, aviation motor oil 40%*
2. *Automobile gasoline 60-70%, auto oil 30’40%*
3. *Kerosene 50-70%, aviation motor oil 30-50%*
4. *Aviation gasoline 15%, kerosene 50%, aviation motor oil 35%*

Ether-less mixture No. 4 can be recommended as the most appropriate for starting and operation of the motor.

On the heaviest grades of kerosene without ether, it is not always possible to start a cold engine. Sometimes it is necessary to preheat the engine by running it with another fuel having some ether, followed by transfer to the heavier ether-less kerosene mixture.

Using a heavy base fuel (kerosene, solar oil), the engine heats up less, works more stably and develops more power than when working on gasoline mixtures, but consumes more fuel. So, for example, a motor with a displacement of 4.5 cc at the maximum steady state consumes 150 cc/hour of the mixture according to the ether-less recipe 2 and 330 cc/hr of the mixture according to the ether-based kerosene recipe no. 3, i.e. more than twice.

The increased fuel consumption when running on kerosene can be explained by the poor volatility of kerosene, which arrives in the combustion chamber in the form of droplets rather than vapors. Only strong compression will cause it to evaporate fully, and even then it only partially burns out, with some being released unburned into the atmosphere.

Selection of fuel mixture

For compression ignition engines, the most diverse fuel blends can be used, but to recommend one as the best is problematic. Engines with little previous running and worn-out engines with poor compression both require the addition of ether to the fuel along with extra oil. When selecting a fuel mixture, it must be borne in mind that the addition of light fractions (such as ether and gasoline) will help in starting the engine. An increase in the percentage of heavy base fuel (kerosene) increases power and improves engine operation. The oil level in the fuel affects the stability of the motor's operating mode as well as its starting performance.

Only through the operation of the motor is it possible to determine how the composition of the mixture affects its starting, power output and operational stability. The fuel requirement can also change over time. During the break-in period, more ether and oil must be added to the mixture. At the end of the break-in period, the engine may be found to start well on gasoline mixtures without ether and on good kerosene. After the engine is run-in, the amount of oil added to the mixture can gradually decrease from 50% to 15%. However, due to wear and compression deterioration, a third period eventually begins when the percentage of oil and ether content in the mixture must again be increased before the engine is completely worn out.

Fuel mixes for glow-plug motors

Methyl alcohol (methanol) is used as the base fuel for glow-plug engines. Since methyl alcohol is toxic, the modeller who uses it must take appropriate precautions.

Castor oil is used as the lubricant for glow-plug engines, in proportions ranging from 15 to 40%, depending on the state of compression of the motor. The oil content in the fuel

should be increased in case of poor starting, unstable operation with seizures and when overheating is detected.

The most widely-applicable fuel is the following mixture (in percent by volume):

Methanol 75%, castor oil 25%

More power can be released by using the following formula (in percent by volume):

Methanol 55%, nitromethane 20%, castor oil 25%

Motors running on methanol have a wide range of stable operating conditions.

If methanol is not available, the following fuel mixtures can be used (in percent by volume):

1. *Ethanol 75%, castor oil 25%*

2. *Ethanol 50%, acetone or benzol 25%, castor oil 25%*

The operating flexibility using these substitute fuels is narrower. If no alcohol-based fuels of any kind are available, it is possible to use diesel fuels containing ether (see page 32).

To obtain a particularly high power from the motor, it is recommended to try adding the following flammable liquids (in percent by volume) to the alcohol mixtures in various formulations:

Benzine	- up to 3%
Butyl alcohol	- up to 10%
Acetone	- up to 5%
Ethyl ether	- 10 - 20%
Nitrobenzine	- 2 - 6%
Nitromethane	- 2 - 20%
Nitropropane	- 2 - 20%
Amyl nitrite	- up to 2%

When selecting a fuel formulation to obtain a specially high power from a glow-plug motor, it is difficult to give precise recommendations, since a mixture suitable for one motor may not be suitable for another. The most advantageous combustion of any fuel mixture in engines depends on various factors, such as compression ratio, scavenging efficiency, cylinder displacement, gas flow diagram, combustion chamber shape, cylinder and piston wall material, glow-plug coil material and configuration, humidity, density and atmospheric temperature, cooling arrangements and a number of other factors. Not all of these factors are easily accounted for.

The aeromodeller should know his engine well and, if he wants to aim for record

performances, should do a lot of experimental work on developing the best fuel mixture for his motor, taking into account the factors listed above.

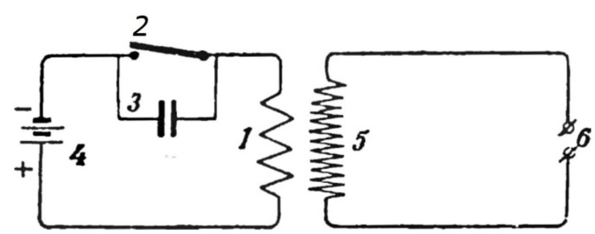
The rules for composing mixtures and selecting constituents for obtaining particularly high power apply not only to engines with glow-plug ignition but also to engines with spark ignition and, to some extent, to compression ignition motors.

When using alcohol combustible mixtures in gasoline engines, the jet size should be increased because fuel consumption is substantially higher with such fuels. When making alcohol-based fuels, it is necessary to ensure complete mixing of the components. A poorly mixed blend will stratify after a while. The mixture should be stored in tightly closed glass bottles and in no case should residual fuel be left in the model's tank. Some liquids in the mixture can dissolve tanks made of celluloid or organic glass, as well as vinyl and rubber tubes that supply fuel to the engine.

<u>Chapter 5 - Ignition Systems</u>

Spark ignition

To generate the electric sparks that ignite the working mixture in the engine cylinder, an induction coil is used. This is shown schematically in the attached figure.



The primary winding 1, to which a low voltage current is supplied from the battery 4, is wound on an iron core. The contact breaker 2 alternately closes and opens the circuit of the primary winding. To reduce the burning of the points, a capacitor 3 is connected in parallel across the contacts. The secondary winding 5 is wound over the primary and has only an inductive coupling with the latter.

When the contacts of the primary winding circuit breaker are closed and then re-opened, the resulting emergent and disappearing magnetic field causes a high voltage current in the secondary winding, discharging in the form of a spark through the spark plug gap 6. This spark causes the ignition of the working mixture.

The presence in the circuit of the low voltage contact breaker mechanically operated by the crankshaft and adjustable by the operator allows one to adjust the ignition timing. Advancing the moment of spark formation in relation to TDC increases the speed of the motor (although only up to a point).

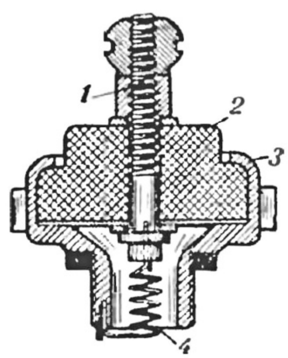
Depleted batteries generate a very weak spark that cannot ignite the fuel mixture. In addition, when starting up, the mixture of fuel and air in the cylinder is often in a

proportion that does not correspond to the maximum flammability of the fuel. This frequently leads to starting difficulties. To enhance the spark, replace the batteries with new ones. Obtaining a good spark depends, among other things, on the size of the gap between the contacts of the breaker as well as on the size of the spark plug gap and the shape of the plug's electrodes.

Glow-plug ignition

In recent years, model aero engines have increasingly begun to use glow-plug ignition. This makes it possible to greatly simplify the model, since the weight of all the ignition components with the battery is from 50 to I00 gm - for small displacement motors, up to 2 or 3 times the weight of the bare engine. As a rule, engines running on glow plugs develop significantly more power. This is partly due to the fact that the portion of the power output used to activate the contact breaker is no longer required.

Moreover, more powerful alcohol-based fuels can be used which increase the amount of energy released during each cycle because their ratio of fuel to air is far higher. Only 8–9 parts of air are required to burn one part of alcohol, whereas for gasoline that ratio is 15-16 parts of air for one part. Therefore each fresh charge of induced mixture contains more fuel with an alcohol blend.



A typical glow-plug is shown in the attached figure at the left. The glowing incandescent body in a glow-plug (the element) is a small wire spiral coil 4. This is mounted in a metal casing 3 with an insulator 2. One end of the coil is attached to the casing, the other to the central electrode 1 which passes through the insulator.

To start the engine, current from a battery or dry batteries is passed through the coil of the glow-plug. When starting the motor at home, you can use alternating current from the bell transformer included in the house lighting network. The voltage for heating the coil should be no more than 1.5 - 2 V. Use a volt-meter to check.

The passage of current causes the coil to glow, the compressed mixture ignites when the engine is flicked over compression and the motor starts to run. As soon as the motor starts, the current source must be disconnected from the glow-plug. The engine continues to run because a thermal and catalytic regime is established In the cylinder in which the coil remains in an incandescent state without external assistance.

Glow-plug motors require special fuel mixtures. They are very sensitive to the quality of the mixture of certain combustibles and generally speaking work well only at maximum engine speeds.

Using his experience with glow-plug motors, the author has been able to achieve stable operation of such motors in all modes (at low, medium and high speeds) using lean, normal and rich mixtures. The experiments on the selection of plug element and fuel

materials were mainly carried out on the author's F-04 "Bumblebee" motor. The compression ratio in this motor is 7 to 1. A glow-plug element made of platinum worked stably for a long time in any given mode, when straight methyl alcohol was used as fuel.

Experiments have shown that on other base fuels the platinum element can only work in a certain selected mode. When the working mixture is leaned or enriched, or when the operating speed changes, the motor stops either due to severe overheating of the coil, which corresponds to pre-ignition in spark ignition engines, or due to a gradual loss of heat by the coil. The catalytic reaction of platinum with alcohol is clearly very important in achieving operational stability.

Despite the high operating temperature (1000–1200 ° C), plug elements made of nichrome alloys behaved on methyl alcohol in the same way as on other base fuels, that is, they worked only in certain selected modes, outside of which the element burned out or the motor stopped due to excessive cooling of the element. It is clear from this that platinum is by far the best material for a glow-plug element.

It is interesting to note that in order to ignite a methanol-based working mixture, a platinum coil must remain heated to 450-500 °C (the beginning of a dark red visible glow). Elements made from nichrome alloys begin to ignite the mixture only when heated to 800–900 C, which corresponds to light-red heating of the coil. Once again, the difference is in the catalytic reaction of the platinum with the alcohol.

Another form of "glow-plug" operation is based on severe overheating of the thin central electrode of a spark plug, which is thermally insulated from the body by a ceramic insulator. Using such a plug, the motor is started with the help of a coil spark ignition system, and regulated with the contact breaker until maximum speeds are achieved. Then the speed is further increased by regulating the needle valve with the air intake wide open. This is continued until a red glow is observed in the exhaust ports. This phenomenon is explained by the fact that the central electrode of the plug begins to glow and illuminate the cylinder wall. In this condition, the motor sharply increases its speed. The electric spark is no longer involved in the operation of the motor and the high-voltage plug lead can be disconnected from the spark plug.

Compression ignition

The third type of ignition system used in model aero engines is self-ignition arising from heat generated through high levels of compression of the fuel mixture.

Self-ignition depends on two factors - temperature and pressure. Ignition of a fuel mixture containing ethyl ether occurs at a compression ratio as low as 16 to1 and at an ambient air temperature of 15–20 degrees C. To obtain the required temperature of the compressed fuel mixture in the cylinder and to regulate the speed and operating mode of the engine, the compression ratio of compression ignition motors (so-called diesels) is usually made variable. It depends on the position of the movable contra-piston.

Chapter 6 - Operation of the Engine in the Model

Engine preparation

Before starting the engine, the aeromodeller must evaluate the amount of compression available in the cylinder and crankcase. If the engine is new or has not been run for a long time, then it is natural to assume that there will be excessive gumming of the cylinder walls and piston crown, while the latter is likely to lose its lubricating film. In both cases, it is necessary to flush the motor with liquid spindle, transformer or crankcase oil, half-diluted with gasoline. Flushing is carried out by pouring diluted oil in small portions into the intake tube of the motor. If fitted, the plug must be unscrewed from the engine and soaked in clean gasoline.

Taking the motor in your left hand, you now need to turn the crankshaft by the propeller with your right hand. Having cranked the motor in this way for 2-3 minutes, let the excess oil drain and wipe the motor clean. To remove excess oil, remove the propeller. Clamp the end of the crankshaft into the chuck of a drill or lathe chuck and turn on the machine at medium speed for a minute or two, holding the motor by the cylinder. After such a break-in of the motor, excess oil will be removed and an oil film will form on all friction parts of the motor.

If the motor becomes hot during the run-in so that it burns the hand, you need to find the point at which excessive friction is occurring and eliminate it. Otherwise, the motor will start poorly, and if it does start, it will work unstably and will not develop the required power.

Having created a lubricating film in the motor, rotate the airscrew in the direction of normal operation, when sounds similar to “chock, chock, chock” should be heard. This is the transfer process: compressed air in the crankcase is entering the cylinder through the bypass and transfer port. If at this time you close the intake tube of the carburetor and close the needle, the sounds will disappear because induction is no longer taking place. This test indicates a well-sealed crankcase cavity.

Screw the washed and dried plug back into the cylinder (assuming that the engine is not a diesel), remembering to place the copper compression gasket under the plug. Turning the airscrew, compress the air in the cylinder and leave the piston at TDC. If after some time the compressed air in the chamber does not lose pressure or only loses it slightly, then we can assume that the motor has good compression. Such a motor will start easily and operate stably at any speed.

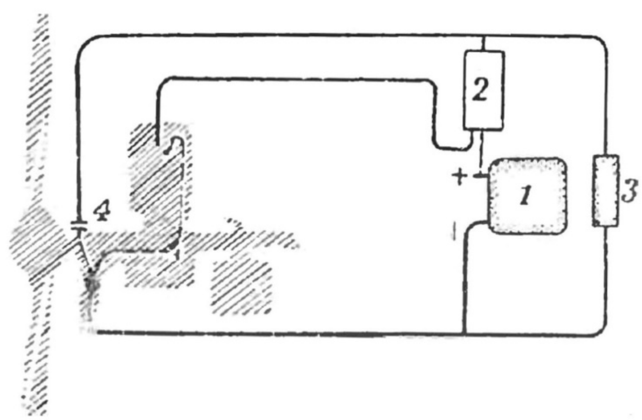
A motor which quickly loses the air pressure in the combustion chamber at TDC requires more energetic flicks when starting by hand. When it does start, it is unstable at low speeds. Motors with poor compression are very difficult to start, and they work well only at maximum speed. To facilitate the starting of such motors, it is recommended that you inject a few drops of oil directly into the cylinder through the exhaust ports to promote a better seal.

The stated provisions apply to all three types of engines - spark ignition, glow-plug ignition and compression ignition (diesels). In addition, before starting any motor it is necessary to check the mounting, gaskets, fasteners, tightness of the propeller, etc.

Starting spark ignition motors

Make a mixture of fuel and oil appropriate for the engine and fill the fuel tank. Mount the motor on a stand or in the model, check the gap between the contacts of the contact breaker, which should be equal to 0.2 - 0.4 mm, and the gap between the electrodes of the spark plug, which should be 0.3 - 0.4 mm.

It should be borne in mind that when checking a plug in the open air, a spark jumps a far larger gap between the electrodes under that condition than it does under gas pressure in the cylinder. If a plug with an excessively large gap or excessive deposits is installed, then under the influence of the compressed working mixture, a discharge between the electrodes can occur along the surface of the insulator. In that case the motor will work intermittently or will not start at all.



After checking the gaps, assemble the electrical ignition support system as shown in the attached figure at the right. The elements of the system are the battery 1, the coil 2, the condenser 3 and the contact breaker 4. The system is grounded on the engine body.

From one to four fresh pocket flashlight batteries are installed on the model as a power source. These are connected ***in parallel,*** otherwise excessive voltage will result in a burned-out coil. With such a connection, the capacity of the current source increases, which is very important for obtaining a good spark over a reasonable running period.

Old depleted batteries have a small capacity. They give a thin, bluish-colored spark that is incapable of igniting the working mixture. With such a spark, do not attempt to start the engine. If you do so regardless, you may achieve individual firing strokes. It may even be possible that the engine will start, but after a short period of operation it will stop. Further attempts to start it will be unsuccessful, and you and others will lose confidence in the performance of your motor. Fresh new batteries have the ability to give a fat red spark. With such a spark, the motor starts quickly and will operate stably for a long time.

After making sure that a spark appears at the plug every time the crankshaft is turned, unscrew the fuel needle a few turns and wait for the fuel flowing out of the jet to fill the carburetor pipe, then close the needle and begin flicking. Make repeated energetic flicks of the propeller against compression in the motor's operating direction, using the index finger and the middle finger of the right hand. With the back of your fingers, the propeller is set up against compression after each flick, and then another flick is applied.

After the first flick, the fuel from the carburetor enters the crankcase cavity and creates a very rich working mixture there which is not capable of ignition. This method at startup gives full confidence in knowing that the fuel has arrived in the engine.

The task is now to ensure that by vigorously cranking the crankshaft, surplus fuel is sucked into the motor. After a few flicks with your hand, the mixture coming from the crankcase up into the cylinder through the transfer port will gradually become leaner and individual firing strokes will occur. At this point, you need to be especially careful and not leave your finger in the prop circle, since following a few individual firing strokes the motor will definitely give a longer firing burst of multiple revolutions.

The first firing strokes of an engine at starting occur on a rich working mixture, but very quickly the mixture depletes to normal. If no action is taken, then since the jet is closed and additional fuel cannot flow from the tank, the mixture continues to lean out and the engine stops due to a lack of fuel supply.

This mode lasts 3 - 5 seconds, and during this time with the left hand you need to slightly open the fuel needle, allowing fuel to flow from the tank. Then, guided by the motor's operating characteristics, adjust the position of the needle.

Adjustment of the motor for best performance is as follows. When the engine is started and warmed up at medium speed (2-3 minutes of operation), the air throttle (if fitted) is smoothly opened. If this causes a reduction in speed, indicating a too-lean mixture, the fuel needle should be unscrewed at the same time.

Regulation of the position of the needle at full speed with the air throttle wide open should be carried out by ear, slowly and smoothly unscrewing or closing it and judging the effect.

The maximum revolutions developed by the motor in a steady operating mode correspond to the normal working mixture being supplied by the carburetor. For further speed increases, the contact breaker is used to advance the ignition timing. The breaker housing is smoothly moved against the rotation of the crankshaft of the motor to a new maximum speed. After advancing the ignition timing, further adjustment of the needle setting is sometimes required. This sequence may need to be repeated several times.

When releasing the model in flight, it is recommended that the needle be set slightly richer than the optimum ground setting. With a slightly enriched mixture, the motor works "softer", while the probability of overheating of the motor is reduced since the

small portion of excess fuel which does not burn in the cylinder due to the shortfall in oxygen takes away some of the heat due to its evaporation. As a result, the cooling and lubrication conditions of the motor are improved. It is also less subject to excessive leaning due to changes of fuel supply head with the model's attitude in flight.

Starting glow-plug motors

To heat the coil of a glow plug, a current source is required only for start-up. As a current source, you can use dry batteries or those used on motorcycles or automobiles. Where there is an electric network, you can use alternating current through a transformer. In all cases, the applied voltage should be 1.5 - 2 V. It is not recommended that you take current from two cells of the battery, since the plug element can burn out when the motor starts.

To start the motor, one wire from the current source is connected to ground (the engine crankcase), and the other to the insulated central electrode of the plug. If, when checking a plug, the element is very hot (bright red or yellow glow) when connected to the current source, then you need to include additional resistance in the circuit. As resistance, you can take a piece of nichrome wire with a diameter of 0.5 mm and a length of 50 - 60 mm. It is convenient to mount such a wire rheostat on a slate plate, making one contact movable so that the resistance value can be easily changed by changing the length of wire and thus the required glow of the plug element can be adjusted.

The engine is best started on a rich mixture in the same way as recommended for spark ignition engines. As soon as the motor starts to run, it is necessary to disconnect the current source from the plug (double heating of the coil with current and firing strokes is undesirable, since the coil can burn out). The engine speed is regulated only by the quantity and quality of the working mixture as adjusted using the fuel needle.

If with an increase in the engine's speed the plug element overheats (which is visible as increased illumination in the exhaust ports) and the motor stalls, pre-ignition is indicated. In this case, you need to place the coil deeper within the body of the plug or increase the distance between the turns of the coil. This is referred to as making the plug "colder".

If, as the number of revolutions increases, the coil remains cool, then it needs to be made "hotter" by slightly extending the coil from the body of the plug or bringing the coil windings closer together. It is necessary to find a position of the coil in the plug body in which the motor develops the greatest power.

A glow-plug engine is stopped by stopping the access of air (closing the intake tube with a throttle or a finger). It is not recommended to stop the motor by shutting off the fuel needle, since the resulting temporarily lean mixture may burn out the coil.

Starting compression ignition (diesel) motors

The starting qualities of compression ignition motors are not associated with any external ignition system, depending solely on the composition of the fuel, the lubricant, the compression ratio and the temperature in the cylinder developed as a result of compression alone. Engine condition also plays an important role.

Consider the influence of each of these factors on the flammability of the working mixture.
The self-ignition qualities of the fuel mixture are greatly affected by its constituents, as can be seen from the following table of self-ignition temperatures of various base fuel components in vapour form:

Kerosene	-	400 degrees C
Gasoline	-	415 degrees C
Ethanol	-	510 degrees C
Benzene	-	520 degrees C

It can be seen from the table that in order to facilitate starting qualities, it is necessary to add a component to the fuel mixture which has a lower self-ignition temperature. Diethyl ether (usually referred to as just plain ether) is most commonly used for this purpose, having a self-ignition temperature of only 160 degrees C.

The laws of physics tell us that when a given mas of gas is compressed, it heats up. When starting, a compression ignition motor develops heat in the fuel mixture which is a maximum at TDC. The temperature necessary for ignition is reached if a certain pressure and associated compression ratio are achieved. Adequate pressure in the cylinder is ensured by a good fit of the piston to the cylinder walls and the presence of an oil film in the gap between the piston and the cylinder. Therefore, the weaker the compression of the motor, the more oil must be introduced into the fuel in order to restore compression.

If the fuel mixture in the cylinder were to be compressed slowly, the generated heat would have time to be transferred to the walls of the combustion chamber, and through them to the surrounding air. In this case, the temperature necessary for ignition would not be reached.

Moreover, with slow compression of the mixture the leakage time for the mixture to escape through the gap between the piston and cylinder wall increases, which reduces both the amount and pressure of trapped fuel mixture, thus indirectly reducing the maximum temperature. Thus, the worse the compression seal of the motor or the higher the self-ignition temperature of the fuel mixture, the more energetically the engine must be flicked to start.

Bearing the above points in mind, the appropriate fuel mixture and the percentage of oil content are selected according to the instructions summarized earlier in Chapter 4.

Starting the motor is approached as follows. Unscrew the compression screw by 2-3 turns. This will reduce the compression ratio well below that required for starting. If fuel

enters the carburetor by gravity, then open the needle valve and allow the carburetor intake tube to fill. If the fuel level in the tank is below the jet, then cover the entry to the intake tube with a finger (choking), unscrew the fuel needle, and turn the airscrew 3-4 times (this process is called “inducing the mixture”).

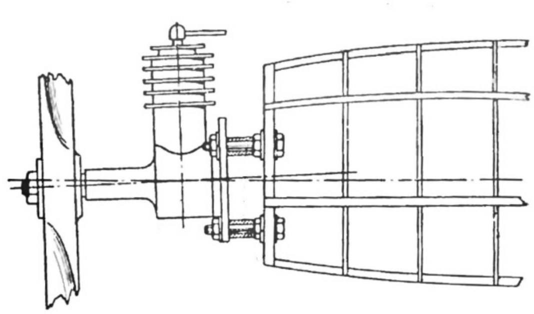
Having sucked the fuel mixture into the engine crankcase in this way, close the needle and continue to flick the airscrew energetically with the fingers of the right hand. While doing this, gradually tighten the compression screw until occasional firing commences. If excessive resistance is felt, then a hydraulic lock may be imminent. In this condition, the compression screw must be slightly unscrewed until the engine turns over and occasional firing commences.

Having established the starting position in this way, a second portion of fuel is sucked into the engine crankcase by choking (if the first one has been consumed). Then, without changing the position of the compression screw but leaving the needle valve open a couple of turns, continue to flick the airscrew energetically. Soon there will be a series of firing strokes, and then the engine will start working. At this time, it is necessary to adjust the needle and compression screw to produce better running.

The maximum speed of the engine is achieved through careful joint regulation of the quantity and quality of the fuel mixture entering the motor and the compression ratio in the cylinder. If sharp metallic sounds are emitted by the motor during operation, this indicates detonation, often caused by excessive compression. In this case, the compression screw must be loosened immediately, since detonation can be very harmful to the engine’s working components.

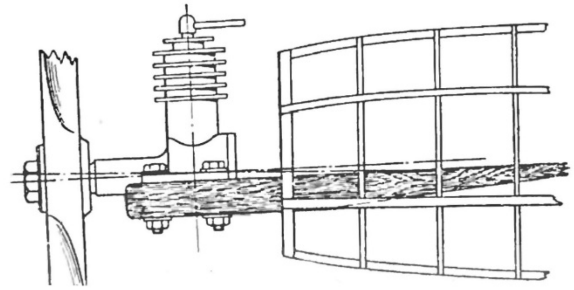
Mounting the motor in the model

The motor must be very securely attached to the model airplane. The nose of the fuselage must be stiff and should not become loose from the motor, otherwise the motor may come off during flight. Sometimes the motor is very securely mounted on the aircraft’s front bulkhead (radial mounting).



Fastening the motor to the front bulkhead with three bolts using spacer tubes and tightening nuts is shown in the accompanying figure at the left. This method is convenient in that it allows one to adjust the direction of the thrust created by the propeller. Unscrewing and tightening the nuts that fasten the motor behind the flange of the rear cover, the motor can be aligned in any direction necessary to counterbalance the torque effect of the airscrew. You can also give the engine a forward tilt to resist the stalling tendencies of a high-wing model. With a large number of nuts, tubes can be dispensed with by replacing them with additional support locknuts.

Another reliable way of mounting the motor is to mount it on beams in the model using the crankcase mounting lugs as seen in the figure at the right. Due to the fact that the mounting beams in the model pass through a series of frames, the beams must be cut to full length from very hard wood and must be at their full cross section at the front bulkhead, otherwise they may break near the frame during a rough landing of the model.

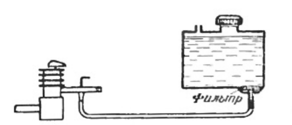


The resistance to the airscrew torque and stalling moment is achieved by the appropriate alignment of the mounting beams during the construction of the fuselage. Fine adjustment can be achieved through the provision of enlarged mounting holes in the beams and by the use of shims under the engine's mounting lugs.

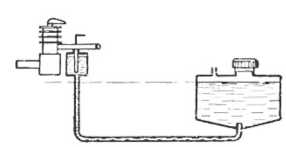
Fuel tanks and fuel feed arrangements

Typically, a fuel tank is installed in the fuselage under the wing so that the fuel consumption in flight does not change the center of gravity of the model. The following fuel supply systems are typically used on models.

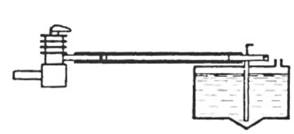
1) The supply tank is remote from the engine and the fuel is fed through a flexible tube directly to the engine's spraybar from the main tank by gravity or by suction.



2) Fuel is supplied through the tube to the motor's built-on fuel tank. The filling hole in the tank must be sealed, otherwise the fuel will leak out when the main tank is located above the engine's tank, and will not be supplied at all when the main tank is located below the engine's tank. In effect, this makes the engine's tank part of the fuel line, also creating a reservoir to allow the engine to continue to function if the supply from the main tank is interrupted.



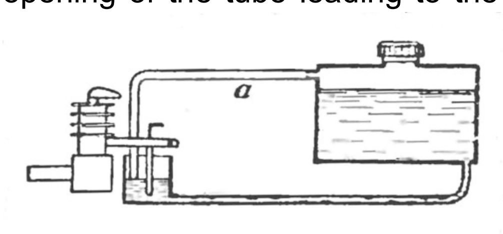
3) The carburetor is removed from the motor and mounted on the main tank. The induction port on the motor and the carburetor mounted on the main tank are connected by a rubber, vinyl or metal tube. The length of such a tube sometimes reaches 300 mm. This method of supplying an engine is convenient for use on model of flying boats and has recently gained considerable popularity.



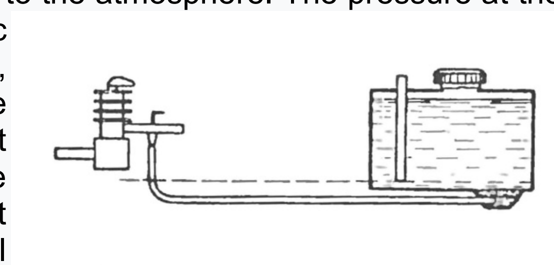
Motors with elongated carburetor intake tubes work more evenly and more steadily, holding their operating mode during prolonged operation. This is because the fuel, passing along a longer path, has a significantly longer time for evaporation and mixing with air. The composition of the working mixture is hence more homogeneous. In addition, the gas flow efficiency of the fuel mixture can be increased through careful selection of the length and diameter of the intake due to inertial and resonance effects.

With a short carburetor intake tube during operation of the motor, pulsation of the fuel mixture can be observed at the air inlet, i.e., its rapid alternate movement back and forth.
With an increase in the length of the intake tube, the pulsation gradually smooths out and the suction in the pipe becomes uniform. Of course, it is possible to increase the length of the tube excessively, since the resistance of the flowing mixture from the tube wall will begin to affect the flow rate.

There are a number of other interesting variations. To maintain a constant level of fuel in the engine's tank, the following system can be used. The filling hole of the engine's tank is connected by a tube to the upper part of the main supply tank. Fuel flowing through the lower fuel tube into the engine's tank rises to the point at which it closes the opening of the tube leading to the top of the main supply tank. This stops any further flow of fuel since no more air can enter the main tank until the fuel level in the engine's tank falls enough to re-open the connection. The fuel level in the engine's tank is thus maintained at the level of the connecting tube's entry point. This system is shown in the attached figure at the left.



The same goal can be achieved by the simpler method shown below at the right. The engine's built-on fuel tank is no longer required. In the main tank, instead of the filling hole there is a soldered vent pipe which is open to the atmosphere. The pressure at the base of this pipe must be atmospheric regardless of the level of fuel in the tank. Thus, in this system, regardless of the fuel level in the tank, all fuel will be supplied at a constant pressure head equal to the distance from the bottom of the tank to the bottom hole of the vent pipe. This ensures a constant head of fuel supplied to the engine.



A float chamber can also be used as a consumable tank, into which fuel enters by gravity from the main tank and is kept at a constant level by a needle attached to the float.

Timing the engine run

For regulated flights of the model when competing in duration or range competitions with a limited time allowed for powered flight, special mechanisms are used to stop the

motor in the air. In earlier times using spark ignition, the flight time of the motor was limited by turning off the ignition. To do this, a special timer was included in the low-voltage ignition circuit, opening the circuit after a set number of seconds or minutes. Timers can be pneumatic or mechanical. Camera timers are generally used to make the latter type.

The pneumatic timer is a cylinder with a closely-fitting piston mounted on a rod. When the rod is pulled upward, air enters the cylinder beneath the piston, and a thin wire coil spring is compressed above the piston. The contacts located on the cylinder cover are closed when the rod is extended. The timer is connected in series to the primary circuit of the ignition system.

In order to activate the timer to turn off the ignition, the adjustable stop on the upper stem is set at the required distance. Then the pin which keeps the stem exposed against the pressure of the spring located in the cylinder above the piston is removed. The coil spring now forces the piston down against the air pressure in the cylinder, displacing air under pressure through a small aperture formed in the base of the cylinder. The aperture is sized so that sufficient pressure is maintained to cause the piston to descend slowly as the air leaks out. When the adjustable stop reaches the spring contact plate on the top exterior of the unit, it opens the contacts of the primary circuit by pressing the spring contact plate downwards. By adjusting the position of the stop, the time for this to happen can be adjusted from a few seconds to several minutes.

The mechanical timing device is a wind-up clockwork mechanism with retardation of the unwinding of the spring through the use of gears with a large gear ratio. A lever is mounted on the winding spring roller, with a spring-activated switch to close the primary circuit The lever is locked in position with a special dog.

When turned on, the clockwork mechanism slowly returns to its original position, sliding the radius part along the lever lock, which keeps the contacts closed. As soon as the spring lever reaches the cut-out in the radius part, a special spring lifts the end of the second lever, breaking the primary circuit contacts.

Compression ignition and glow-plug engines present a different problem, because there is no electrical ignition circuit. To stop such an engine in the air, a special valve activated by a timer can be fitted to the crankcase. When the crankcase valve is opened, the crankcase interior communicates with the atmosphere. As a result, the crankcase seal is broken, suction through the carburetor is interrupted and the motor stops.

The engine can also be stopped by having the timer open a specially-made hole in the intake pipe between the jet and the induction port. This destroys the engine’s suction and hence its fuel supply. Alternatively, a purpose-built timer-controlled cut-out can be included in the engine’s fuel line to stop the flow of fuel directly.

The simplest way to limit the running time of an engine is to limit its airborne consumption to a measured (usually small) amount of fuel. To do this with a diesel

engine, a small tank in the form of a tube with a capacity of I — 5 cc is glued from celluloid. The tank is positioned above the jet and connected to it using a flexible tube. On the side wall of the tank, a series of level marks are included. The tank is filled with fuel, the motor is started and the time of fuel consumption between the marks on the tank is recorded using a stopwatch (times to lower the fuel level from the first, second, third, etc. marks). Such a tank will not work with a glow-plug engine because the alcohol fuel will attack the celluloid.

When starting the engine in competition, proceed as follows. With the help of a medical syringe, fill the tank with fuel to the top, bring the model to the launching area, start the engine and adjust the motor, all the while monitoring the level of fuel in the tank. As soon as the fuel level has dropped to the pre-determined mark for the desired running time, launch the model.

With this method of limiting the duration of the motor run, the modeller can be sure that the motor will undoubtedly stop at more or less the correct time. Those who use timers often experience flyaways in competition flights due to the fact that something sticks in the mechanism or even that they forgot to turn on the timer! In addition, the use of timers increases the weight of the model.

Preparation of the model for record attempts

In preparing the model for a duration, range or altitude record flight, the motor must be "test-driven" in the model under conditions close to flight. For that mode, you need to restrain it with a wire, restricting all movement up and forward, and then run the engine. During the test it is necessary to make the following checks:

1. check the ability of the motor to run for the required time on the fuel being supplied;

2. check the rate of fuel consumption;

3. check the reliability of the ignition system (if fitted) and the capacity of the tank;

4. check the reliability of the fuel supply system and the effect of a change in fuel level on the operation of the motor;

5. check the security of the motor mount and all associated accessories;

6. select and make note of the position of the throttle and needle valve

The motor must be "driven" until all possible causes of the motor stopping before the appointed time have been eliminated and the motor has worked for the set time without additional adjustment. It must be borne in mind that in flight, the operating conditions of the motor change, since pressure, temperature and humidity change. In addition, the model will likely vibrate more in the air. All of this can cause the motor to stop

prematurely. When launching his model on a record flight, the aeromodeller must take such factors into account, otherwise it is impossible to be assured of a good result.

If the engine is a spark ignition type running on flashlight battery power for an extended period, the batteries will inevitably become depleted and after a while the spark will become so weak that it is not able to ignite fuel vapors and the engine stops. To make better use of the available battery capacity and to maintain ignition with a weakened spark, experienced modellers add 5-10% ethyl ether to gasoline, the vapor of which has a flash point well below the flash point of gasoline vapor. This increases the functional operating time of the ignition batteries installed on the model, and thereby the potential duration of the powered portion of the flight.

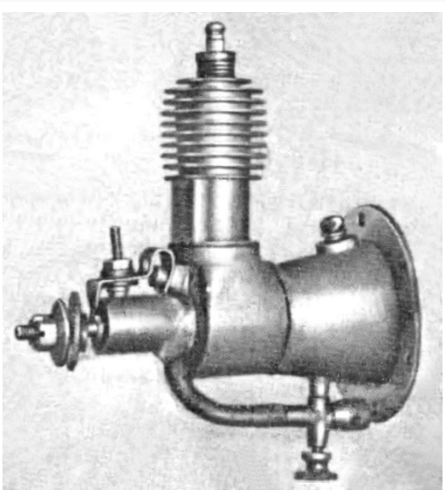
Chapter 7 - Soviet Model Engines

General information

The model aero engines described below have been used successfully on flying models by both ordinary amateur fliers and aeromodelling record holders in the USSR. The AMM-4 and AMM-5 units have been mass-produced in large numbers. The K-16 and CAML-50 motors are also mass-produced. The MZ-2, F-10, F-12, MK-30, VIP-11 and OK-20 designs were released in far smaller numbers. All other featured motors were made as individually-constructed prototype examples only. Despite this, they are of great interest from a technical standpoint, indicating different approaches to the creation of more perfect designs and demonstrating various options for solving particular problems.

GASOLINE (SPARK IGNITION) ENGINES

MZ-2 spark ignition engine designed by M. Zurin



The MZ-2 motor (left) was one of the first Soviet model aero engines to enter series production, showing a good performance. The 4.58 cc motor starts easily, runs steadily and has a low weight (150 g). The bore is 18 mm, the stroke is 18 mm, and the engine power at 4,500 rpm is 0.11 BHP.

Induction is by crankshaft front rotary valve, while cross-flow loop scavenging with a deflector piston is used. The fuel tank also serves as the radial motor mount, by which the motor is attached to the front bulkhead of the model's fuselage.

About 100 of these engines were manufactured at the Central Aircraft Model Laboratory (CAML) in 1940. Despite the limited scale and time of

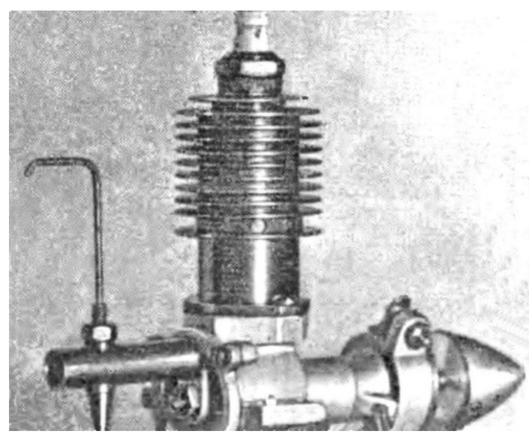
their manufacture, many of these motors are still in operation today and still showing good results. For example, the famous model aircraft designer Y. Sukhov annually demonstrates flights of his models with an MZ-2 engine over distances of 100-150 km. (*these statements may be artefacts from the 1951 first edition - Ed.*).

F-3 gasoline engine designed by A. Filipichev

This motor has a displacement of 2 cc with a bore of l4 mm and a stroke of 13 mm. At 7,500 rpm its power output is 0 I I BHP. The motor has a bare weight of 72 gm. In general design terms, the F-3 motor resembles the F-4 “Bumblebee” unit (see below), although it is structurally somewhat different. Despite the small displacement, the motor runs at high speeds and develops relatively high power for its size (*unfortunately the image of this engine did not scan even partially*).

“KOMAR” (Комар - Mosquito) gasoline engine

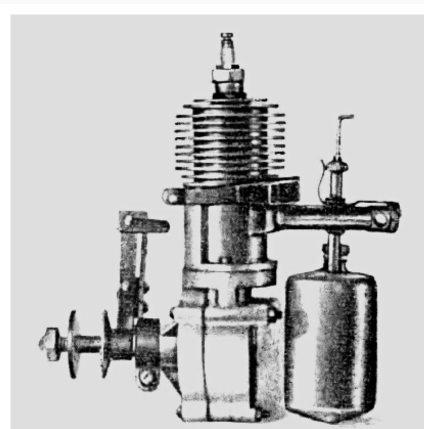
Designed by A. Filipichev, this motor has a displacement of 5.1 cc based on a bore of 19 mm and a stroke of 18 mm. Power output is 0.10 BHP at 4,500 rpm. Rear rotary disc valve induction is featured.



The most original design feature of this engine is the absence of a bypass passage - transfer is accomplished entirely through a piston valve. The valve opens to transfer the mixture under pressure from the crankcase and closes at the beginning of compression in the cylinder. This type of valve was described above in Chapter 2. Induction is by disc rear rotary valve.

At the 1947 all-USSR model engine competition, the author was awarded first prize in the class of motors with displacements of up to 5 cc. (*Sadly, this image scanned only partially, but the partial image is included regardless above at the right because it’s far better than nothing!)*.

AMM-5 gasoline engine



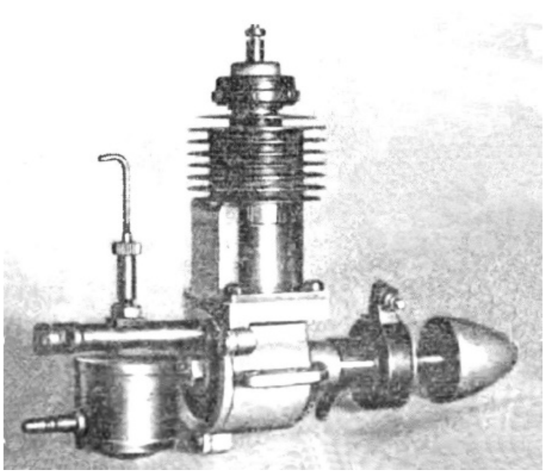
This motor was manufactured for a long time and was the most widely-used model aero engine in the USSR for some years. Numerous changes were made to the design over time, and its variants were released under the series identification designations AMM-I to AMM-5. The last AMM-5 variant is illustrated at the right. (*Note that the engine bears a more than passing resemblance to the Brown Jr. - Ed.*).

Specifications:

Bore - 22 mm
Stroke - 25 mm
Displacement - 9.5 cc
Peak output - 0.15 BHP
Maximum revs - 4,500
Bare weight - 300 gm

*F-4 “SHAMYEL” (***Шмель** - *Bumblebee) gasoline engine*

Designed by A. Filipichev, this motor (seen below at the left) has a displacement of 9.95 cc with a bore of 24 mm and a stroke of 22 mm. The motor weighs 300 gm with airscrew. Maximum power is 0.30 BHP at 6,300 rpm. At the model engine competition in 1947, the author was awarded the second prize in its category for this motor.



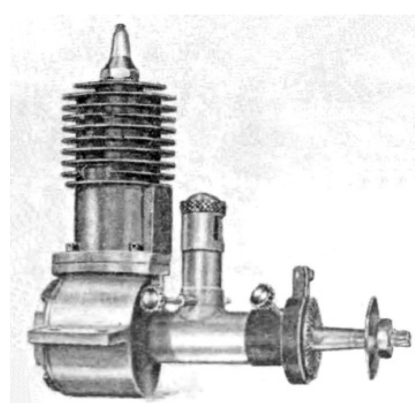
Rear rotary disc valve induction is employed. The induction port is controlled by a disc rotating on a central bearing and driven by the crankpin. By aligning different holes in the disc with the crankpin, the motor can be configured for either right-hand or left-hand operation.

The “Bumblebee” subsequently demonstrated good performance when running on glow-plug ignition. The famous aeromodelling champions M. Vasilchenko and B. Martynov set several records with the “Bumblebee” engine, including International ones. Small improvements and fine-tuning of the engine have resulted in the development of up to 0.90 BHP on glow-plug ignition using “hot” fuels.

At the end of the book in Appendix 3 you will find working drawings of the components of the “Bumblebee” motor. Based upon these drawings, the motor can be constructed with either spark or glow-plug ignition. The necessary notes appear on the drawings. The circuit breaker is not required for operation of the engine with glow-plugs.

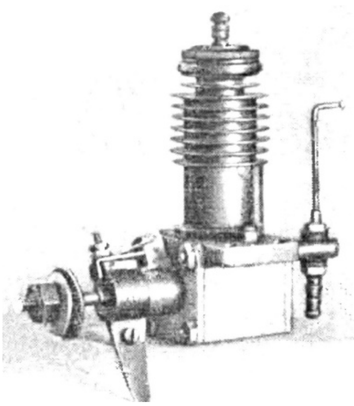
MB-02 gasoline engine

Designed by V. Petukhov, this motor (seen at the right) has a displacement of 9.97 cc, with a bore of 23 mm and a stroke of 24 mm. The motor develops a maximum output of 0.40 BHP at 6,600 rpm. Induction is by crankshaft front rotary valve. The engine features cross-flow loop scavenging with a deflector piston.



At the model engine competition in 1947, the designer of this motor was awarded the first prize in the category of motors with a displacement of 10 cc.

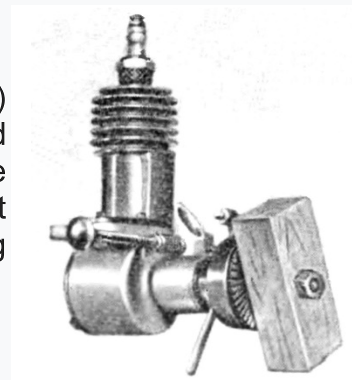
F-5 gasoline engine



This motor (left) was designed by A. Filipichev and built at CAML. It was primarily designed for use in control line models. A bore of 19 mm and stroke of 16 mm give it a displacement of 4.54 cc, with a weight of 200 gm. The motor develops up to 4,500 rpm, while producing around 0.10 BHP.

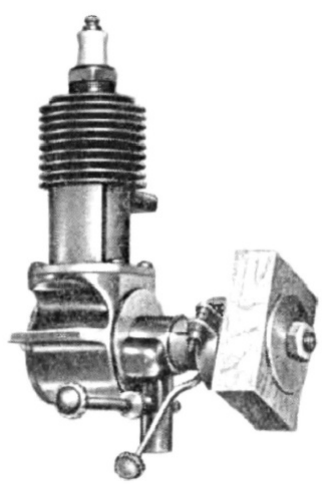
All details of the F-5 motor (seen at the left) are simpler and easier to construct than most other motors, making the engine very suitable for home construction. The model record holder S. Malik flew 5 km in a straight line during a test flight with this motor.

MB-01 gasoline engine



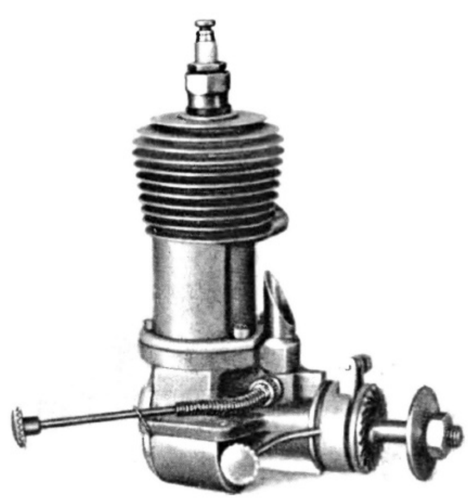
Designed by V. Petukhov, this smaller motor (seen at the right) has a displacement of 2 cc resulting from a bore of 14 mm and a stroke of 13 mm. The motor develops up to 0.10 BHP. The bare engine without a coil weighs only 75 gm. Crankshaft front rotary valve induction is used, with cross-flow loop scavenging and a deflector piston.

MB-03 gasoline engine



Designed by V. Petukhov, this motor (seen at left) has a displacement of 5.09 cc from a bore of 18 mm and a stroke of 20 mm. The bare weight is 150 gm. Cross-flow loop scavenging is featured along with a crankshaft front rotary induction valve. The motor develops 0.16 BHP.

MB-05 gasoline engine

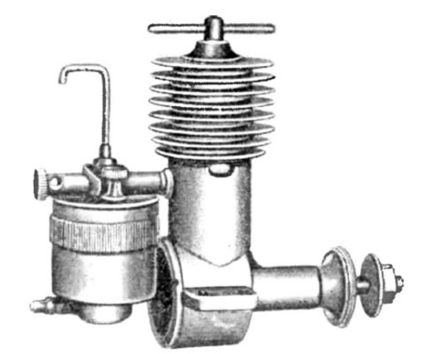


Designed by O. Gajevski, this motor (seen at the right) has a displacement of 9.97 cc from a bore of 23 mm and a stroke of 24 mm. Crankshaft front rotary valve induction is used along with cross-flow loop scavenging and a lightweight deflector piston. With the correct airscrew selection, the motor develops an output of 0.72 BHP at 11,000 rpm.

In 1949, O. Gajevski's control line speed model with this engine achieved a speed of 169 km per hour, which was a great achievement for this class of model at the time.

COMPRESSION IGNITION (DIESEL) ENGINES

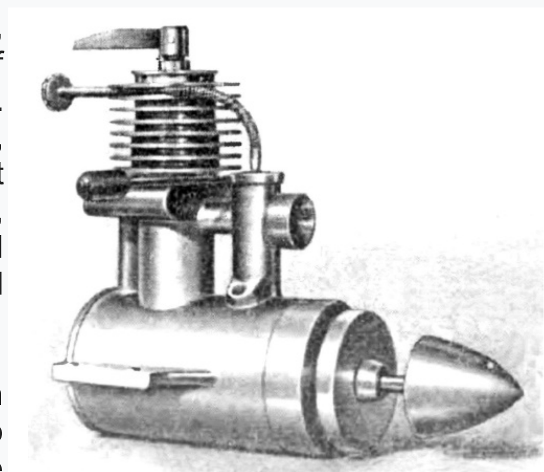
F-10 diesel



Designed by A. Filipichev, the F-10 motor, which was the first successful Soviet compression ignition engine, was first shown at the XV All-Union Competition for flying models in 1946 and received the highest rating in its category at the motor competition in 1947. The motor has a bore of 17 mm, a stroke of 20.8 mm, a displacement of 4.72 cc and a power output of 0.16 BHP at 4,500 rpm. The motor weighs 196 gm.

The F-10 motor is seen at the left. Fuel induction takes place through a cylinder port (*sideport induction*). The bypass passage is formed by a longitudinal channel cut into the front wall of the cylinder liner and located between the walls of the crankcase and piston. This cylinder design was illustrated earlier in Chapter 3. Scavenging is accomplished using a single transfer port and two exhaust ports.

F-12 diesel

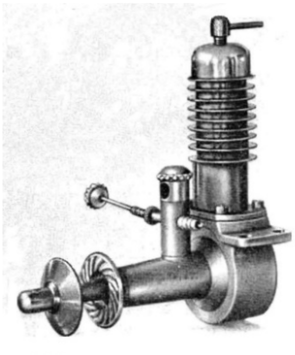


Designed by A. Filipichev and seen at the right, this unusual sideport motor has a displacement of 4.42 cc, a bore of 16 mm and a stroke of 22 mm. Power output reaches 0.21 BHP at 5,500 rpm, with a weight of 300 gm. The motor is built around a main unit which includes the crankcase, bypass channel, exhaust stacks, carburetor and fuel tank, the latter being located at the front and surrounding the main bearing housing.

The carburetor of the motor is constructed to an original design using a forward-facing intake to take advantage of slipstream pressure to promote improved air induction.

The motor is very conveniently arranged for mounting in free flight models, since having an extended crankcase, it imparts an elegant shape to the model. At the XVII All-Union competition in 1948, a motor of this type was installed on a radio-controlled model. At take-off, the model weighed 4.5 kg at a wing loading of about 35 gm/dm^2. It took off easily from the ground and flew well.

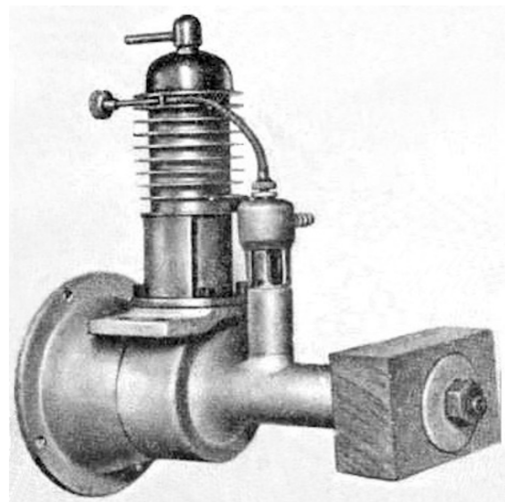
MK-02 diesel



Designed by V. Petukhov, this motor (seen at left) has a displacement of 2.5 cc and develops an output of 0.13 BHP. At a model flying competition in 1948, a scale model powered by this engine flew 28 km, which was then a record for a scale model of a Soviet aircraft.

At the All-Union model aircraft competition in 1949, the model of Y. Sokolov powered with the MK-02 engine was awarded a prize by the Ministry of Aviation Industry.

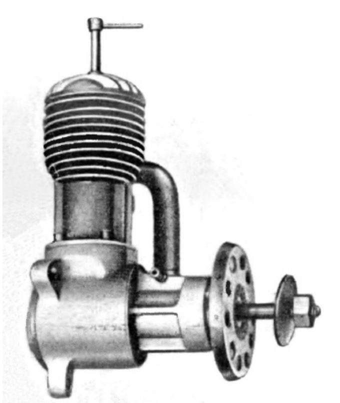
MK-03 diesel



Designed by V. Petukhov, this motor (seen at the right) has a displacement of 7.54 cc with a bore of 20 mm and a stroke of 24 mm. The engine develops 0.26 BHP at 5,200 rpm. The maximum speed with a 360 mm diameter airscrew is 6,000 rpm. The motor weighs 280 gm, fuel consumption is 360 gm/hr. S. Malik's model using this engine set a world record in 1947 with a flight distance of 215 km.

Crankshaft front rotary valve induction is used. Cross-flow loop scavenging is featured, with a step in the piston crown on the transfer side. The carburetor of the motor is constructed to an original design using an axial spraybar instead of the more usual transverse component. Such a carburettor was illustrated in Chapter 3 above. The rear cover is made in the form of a cone with a flange for radial mounting of the motor on the front bulkhead of the model.

MK-09 diesel

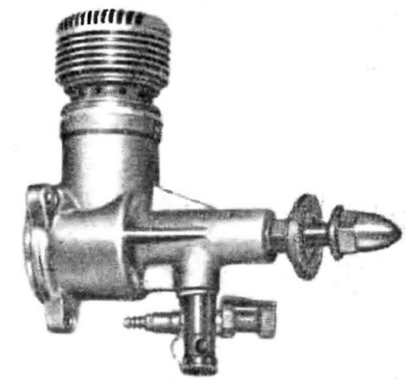


Designed by V. Petukhov, this motor (seen at the left) has a displacement of 6.91 cc with a bore of 20 mm and a stroke of 22 mm. Crankshaft front rotary valve induction is used, with an unusual extended intake tube. In standard form, the motor develops 0.55 BHP at 9,500 rpm. Its designer V. Petukhov used this engine at the All-Union model aircraft competition in 1949 to achieve a flight of 128 km.

For the first time in the USSR, two ball bearings were used on this motor as crankshaft bearings. After some modifications, the engine ended up developing 0.62 BHP at 10,500 rpm.

OK-20 diesel

Designed by O. Koshevoy, this motor (seen at the right) has a displacement of 3 cc with a bore of 15 mm and a stroke of 17 mm. The motor develops 0.12 BHP at 5,000 rpm. It weighs 200 gm.

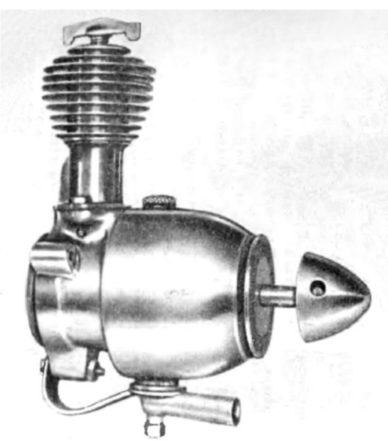


The most original design feature is the absence of a contra-piston, the cylinder being blind-bored. The compression ratio during start-up and operation of the motor is regulated by screwing in or unscrewing the entire cylinder in the crankcase. The lower part of the cylinder has a thick wall with external threads cut along its entire length. 12 vertical holes are drilled in the thickness of the lower cylinder wall to form the bypass channels. 12 connecting holes are drilled into the cylinder wall to serve as transfer ports. The exhaust ports consist of a similar ring of drilled holes at a higher level. The porting is thus radially uniform, with operation being unaffected by the cylinder's radial alignment.

The motor starts and runs well on fuel mixtures containing ether. However, due to the lack of a compression locking system, the compression adjustment sometimes changes during operation, which adversely affects the motor's performance.

The carburetor of the motor is both simple and reliable. This carburetor was also installed on the K-16 series production engine.

KMK-1 diesel



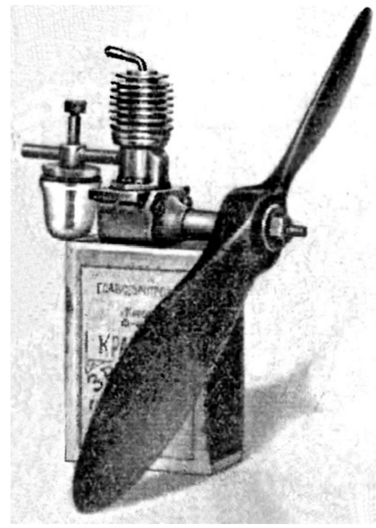
Designed by I. Kulikovski, this motor (seen at the left) has a displacement of 4.28 cc with a bore of 16.5 mm and a stroke of 20 mm. It develops 0.16 BHP at 5,000 rpm, with a weight of 350 gm. The KMK-1 has a standard gas distribution system, with a crankshaft front rotary induction valve and cross-flow loop scavenging.

The cylinder is made of alloy steel, with a brazed bypass channel. The piston is made of fine-grained cast iron, the connecting rod is made of solid aluminum alloy without bushings. The fuel tank is incorporated into the design of the crankcase at the front. This tank design has many joints that require a special seal or a very precise fit, and in all honesty cannot be recommended.

The motor's carburetor has an unregulated fuel jet. The mixture is regulated by a throttle, made in the form of a tube which fits over the inlet. By screwing and unscrewing this throttle, one can change the flow area for incoming air. The carburetor has a rotating air intake tube. When rotated sufficiently, the air intake can be completely covered, thereby stopping the engine.

F-15 diesel

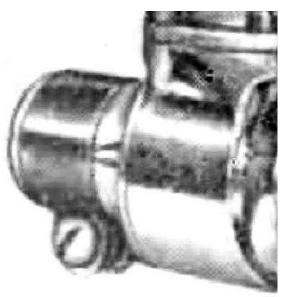
Designed by A. Filipichev, this tiny motor (below right) has a displacement of 0.4 cc with a bore of 8 mm and a stroke of 8 mm. The little motor weighs only 29 gm. It is relatively easy to start and operate. However, motors with such small displacements are of little practical interest due to their low power and extremely small size.



In 1948, S. Bashkin built motors in the Moscow Central Model Aircraft Laboratory (CAML) with an even smaller displacement of 0.33 cc. These motors had a bore of 6.5 mm and a stroke of 10 mm. They were demonstrated at indoor competitions in Moscow and showed good operating characteristics. However, such motors are very rare, in large part due to the fact that it is very difficult to construct them successfully.

MK-05 diesel

Designed by V. Petukhov, this motor has a displacement of 0.98 cc with a bore of 10 mm and a stroke of 12.5 mm. It weighs 58 gm. The engine runs at 6,500 rpm.



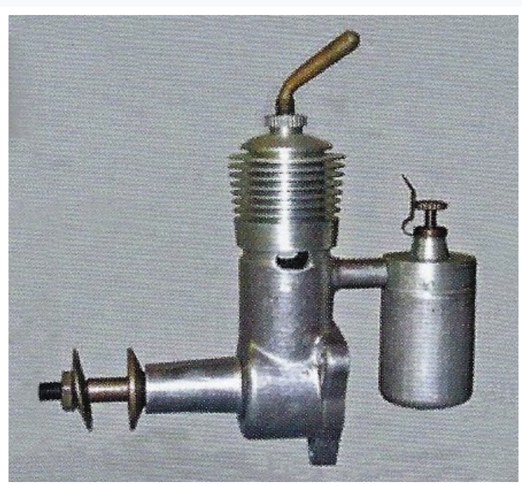
The motor mount is the main feature of interest. The backplate of the motor has a short split tube added to its rear face, into which a closely-fitting cylindrical wooden mounting bar fixed to the model is inserted. Using a clamping screw and nut, the backplate tube is tightened onto the wooden bar. With this mounting method, the motor can be quickly removed and installed in any orientation. The attached image at the left shows some of the relevant details of this arrangement.

MK-06 diesel

Designed by V. Petukhov, this motor has a displacement of 1.7 cc with a bore of 12 mm and a stroke of 15 mm. The motor weighs 72 gm (*no image of this model is available*).

CAML-50 diesel

This sideport 1.8 cc diesel motor was designed at the Central Aircraft Model Laboratory (CAML) in Moscow specifically as a home-construction project for modellers and model engineers. It was also produced in series. Examples were home-constructed in considerable numbers. Many builders made their own modifications to the design, including displacement increases.



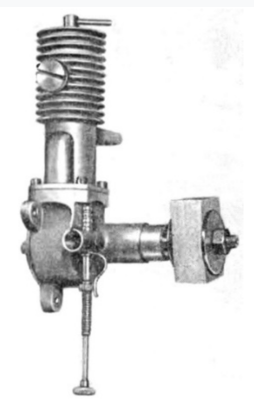
Examples have been made with displacements ranging from 1.8 cc (as originally designed) up to 2.46 cc, the latter displacement being achieved by increasing the bore from 12 mm (as originally designed) to 14 mm.

Plans and construction details for this motor are included near the end of this book.

Specifications:

Type	-	compression ignition (diesel)
Scavenging	-	reverse flow, twin ports
Bore	-	12 mm
Stroke	-	16 mm
Displacement	-	1.81 cc
Compression ratio	-	variable
Normal operating speed	-	4,000 - 4,500 rpm
Output	-	0.06 BHP
Induction period	-	112 degrees
Transfer period	-	110 degrees
Exhaust period	-	126 degrees
Cooling	-	air

MKB-01 multi-ignition motor



Designed by V. Petukhov, this very unusual crankshaft front rotary valve motor (seen at the left) is arranged to operate either as a gasoline engine or as a compression ignition unit. There is a contra-piston and compression screw as well as a hole for the plug in the side of the cylinder. The plug mounting hole can be sealed with a cap-screw for operation as a diesel, as seen in the accompanying image. The motor has a displacement of 1.1 cc and runs in the region of 4,000 rpm in either gasoline or diesel mode.

K-16 diesel

The K-16 motor (right) is still in current production *(possibly a residual reference from the 1951 first edition - Ed.*) and is primarily intended for use in model aircraft, although it can also be used successfully to power model boats and cars. The engine is very flexible and will operate successfully on a basic fuel mixture consisting of low-grade kerosene, ether and oil in equal proportions.

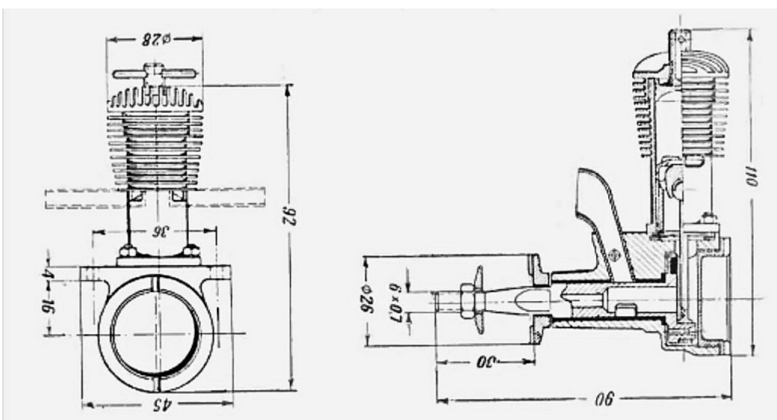
Specifications:

Type	-	compression ignition (diesel)
Scavenging	-	reverse flow
Bore	-	16 mm

Stroke	-	22 mm
Displacement	-	4.4 cc
Compression ratio	-	variable
Normal operating speed	-	5,000 rpm
Max. operating speed	-	6,500 rpm
Operating direction	-	right-hand
Output	-	0.12 - 0.15 BHP
Fuel	-	equal parts kerosene, ether and MK grade oil
Cooling	-	air
Bare weight with airscrew	-	280 gm
Airscrew diameter	-	350 mm
Working life	-	15 hrs.

MK-4 diesel

Designed by B. Martynov, this motor was used in 1949 to set an international record for free flight speed for land-based models. In the same year, a second speed record was set by the same engine in a free flight model flying boat. In 1950, the MK-4 engine was used in a flying wing model to establish an international free-flight speed record for tail-less model aircraft (*no photograph available - see drawings below*).



The motor (left) has a displacement of 4 cc. The compression ratio is variable in the range 16–20 to 1, the operating speed range is 5,100–5,900 rpm, and the bare weight is 160 gm.

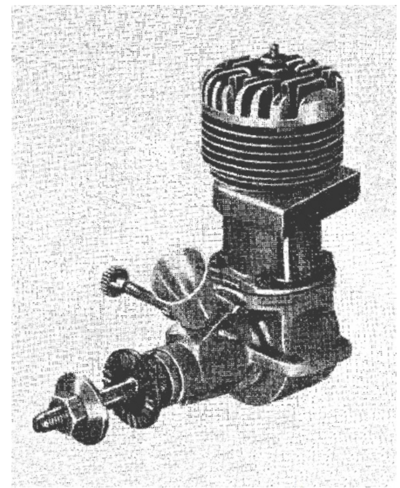
A distinctive feature of the motor is its use of a refined piston valve for fuel mixture transfer. In the crankcase, under the cylinder liner, a ring of oil-resistant non-metallic material is installed to serve as a mechanical stop for the piston skirt. When the piston reaches 40° before BDC, it contacts the ring and can descend no further. However, the piston valve is directly connected to the connecting rod, hence continuing to descend and opening the valve, through which transfer then takes place. Thus the valve is opened and closed mechanically rather than relying on gas pressure. A minimum transfer period of 80° in thus assured.

The motor was usually installed in an inverted position (i.e., cylinder down). For the removal of spent gas, the motor has exhaust stacks. The intake is angle forward to take full advantage of the slipstream pressure.

GLOW-PLUG MOTORS

MB-05F glow-plug motor

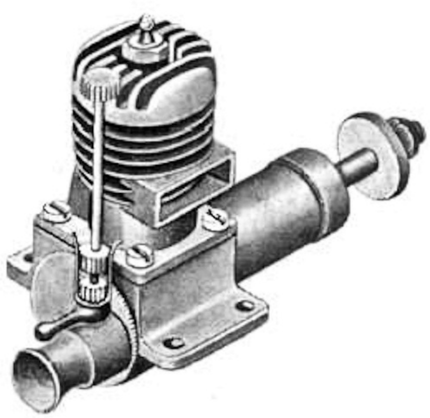
Designed by O. Gajevski, the MB-05F motor of 9.97 cc displacement (seen below at the right) is a further development of the MB-05 motor described earlier in this chapter, which operated on spark ignition. The engine has a bore of 23 mm and a stroke of 24 mm. It weighs 300 gm.



The new variant features increased finning on the cylinder head. The shape and position of the intake tube has been changed, with a bell-shaped entry which promotes more efficient induction of air. The new model is not fitted with a contact breaker, being designed to operate only as a glow-plug unit.

With careful tuning of the engine and the use of glow-plug ignition, it was possible to increase the power above that achieved by the spark ignition variant described earlier. An output of 1.2 BHP at 13,000 rpm has been measured. A control-line speed model using this engine achieved a speed of 180 km/hr. (*Editor's note - most of this reads like an artefact carried over from the 1951 first edition*).

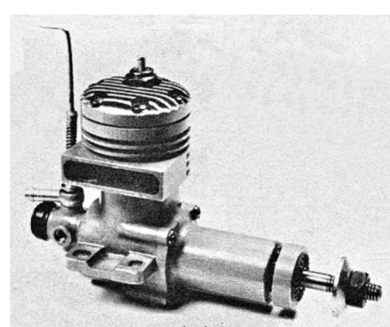
MB-09 glow-plug motor



Designed by V. Petukhov in 1952, the MB-09 motor seen at the left is designed specifically for glow-plug operation. It has an elegantly simple external shape and is distinguished by the thoughtfulness of all the details. Bore is 15 mm and stroke is 14 mm, giving a displacement of 2.47 cc. The compression ratio is 8 to 1, while weight is 105 gm. Cross-flow loop scavenging is employed along with a deflector piston.

The crankshaft rotates in two ball bearings, while the induction process takes place through the rear cover of the crankcase, being timed by a rotary disc valve. This ensures the highest possible strength of the crankshaft, permits reversibility of operation and yields the most advantageous gas distribution diagram.

When working on straight methyl alcohol with a glow-plug, the motor originally developed an output of 0.25 BHP at 17,000 rpm. A control-line model fitted with this engine reached a speed of 115 km per hour on this fuel.



(*Editor's note - the MB-09 was further refined during the mid 1950's, eventually developing 0.37 BHP and achieving a best speed of 183 km/hr in 1956, which would*

have been good enough to win the previous year's World Control Line Speed Championship. It also set a free flight speed record of 129 km/hr. It is very significant in being the first truly up-to-date and potentially competitive International-class competition glow-plug unit to appear in the USSR. It was subsequently further developed into the excellent VIP-20 design of 1960 seen above at the right).

Editor's note - the next section of the book is taken up with details of how to make the components of a spark ignition system (coils, harnesses, spark plugs, etc.) as well as making one's own glow-plugs. The final section consists of complete instruction for making the previously-described 1.8 cc CAML-50 diesel engine and "Bumblebee" 10 cc sparker, including plans (which did not scan well enough for reproduction).

This material has been omitted from this translation as being of very little practical or historical interest to present-day model engine enthusiasts, particularly in the absence of useable plans.

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Editor's note: "Osoaviahim" denotes the "Society for the Assistance of Defense, Aircraft and Chemical Construction". This organization was the predecessor of DOSAAF. "Oborongiz" was a Russian state-controlled publishing house. Osoaviahim appears to have taken over responsibility for publishing model literature soon after WW2, being itself re-constituted as DOSAAF in 1951.